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# Corrosion Coupons and Pipe Life Predictions—Revision of 1947

*By W. R. Schneider*

**Bureau of Tests and Inspection, Pacific Gas & Electric Co., Emeryville, Calif.**

"CORROSION Coupons" or "Steel Test Plates" are removable steel plates buried near a pipeline or other structure, on which it is desired to know the rate of corrosion which takes place over a period of one or more years, due to soil action, stray railway currents, long line currents, etc.

The coupons are installed in pairs at the following locations:

1. Wherever the general electrolysis survey indicates that the steel pipe is discharging an electric current into the soil at a rate of one or more milliamperes per square foot of exposed pipe surface.
2. Where appreciable pitting has been found on examination of the pipe surface.
3. Where pipe failures have occurred.
4. At the limits of, and in cathodically protected areas, and at the limits thereof, to show the effectiveness and extent of the protection.

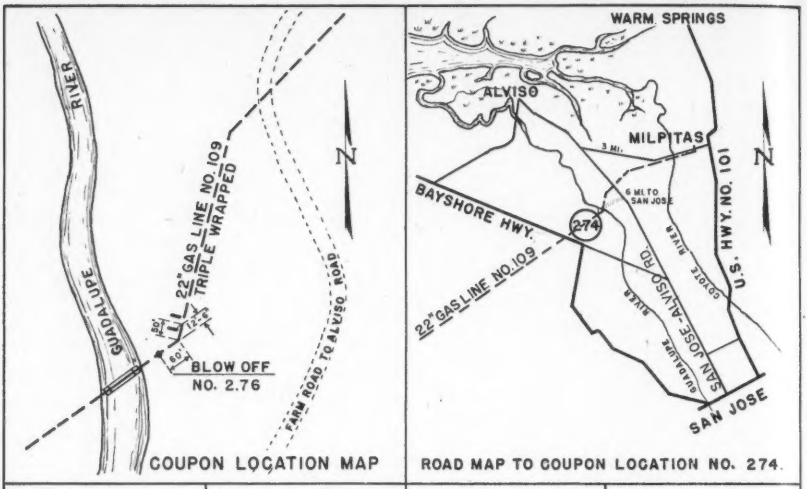
The data obtained by the annual study of a series of coupons covering a period of years are used to estimate the probable life, or date of the first failure of the pipe, and the economic feasibility of applying one of the different types of pipe protection now available.

The coupon serial numbers, installation and removal dates, pit depths and other data, and a map showing the location of the coupon station in the field are recorded in Figure 1.

When corrosion coupons are installed on pipes covered by protective coatings or wrappings, it is necessary to consider the degree of protection given by the pipe covering. This can be determined by measuring the current flow in the pipe on each side of the corrosive area, or coupon location, to show if a current is lost from the pipe to the soil through the wrapping. This latter test can frequently be made by the use of an earth current meter, of the McCollum type, to measure the current passing through the low resistance portions of the pipe covering to the soil. The contactor in this case is placed directly against the covering of pipe.

Coupons connected to a pipe covered with a coating having high insulating properties (at the suspected location) could still show signs of corrosion, but would not show the true condition on the pipe surface.

An obvious example is that portion of a pipe which crosses a marsh on a trestle. A coupon buried in the corrosive soil of the marsh and connected to the pipe on the trestle would show considerable loss of weight and pitting due to the galvanic potential existing between the marsh soil and the higher soil on either bank. The corroded condition of the coupon would not be indica-




PIPE O.D. 22 IN. | WALL THICKNESS 0.3125" | PROTECTION T.W. | DATE INSTALLED 1936

EXPOSED PLATE AREA 26.81 SQ. IN | LOG SHEET NO. 3730

| COUPON NO. | INSTALLED DATE | INSTALLED GRAMS | REMOVED DATE | REMOVED GRAMS | RUN IN DAYS | WT. LOST | LOSS SQ. FT. PER YEAR | MAX. PIT /YEAR P. | CHANGED BY | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 4219 | 11-5-40 | 698.8 | 10-27-41 | 675.0 | 356 | 23.8 | 105.5 | .008 | | TO PIPE |
| 4220 | " | 713.5 | " | 701.0 | " | 12.5 | 55.5 | .011 | | CONTROL |
| 4793 | 10-27-41 | 707.0 | 11-16-42 | 686.1 | 385 | 20.9 | 84.0 | .019 | | TO PIPE |
| 4794 | " | 703.2 | " | 665.6 | " | 37.6 | 150.6 | .022 | | CONTROL |
| 5683 | 11-16-42 | | | | | | | | | TO PIPE |
| 5684 | " | | | | | | | | | CONTROL |

Figure 1—Corrosion coupon location on Pacific Gas and Electric Company gas transmission line No. 109, near Guadalupe River (California) crossing.

tive of the corrosion on the pipe at that location, which is obviously not affected by the corrosive marsh mud below. The insulated pipe would merely act as a conductor between that portion of the pipe in mildly corrosive soil on the distant bank and the corrosion coupon in the highly corrosive mud of the marsh.

The corrosion coupons are 3" x 6" x 5/16" steel plates, cut from 5/16" x 3" hot-rolled steel bars. These coupons, shown in Figure 2, are cleaned by sand blasting; then drilled, numbered and weighed.

Coupons obtained in this manner have been found to give better results than those obtained from plates cut from the steel pipe. The cost of the former is considerably lower. The increased facility of measuring pit depth on a flat plate increased the accuracy of these measurements.

No difference has been found between the pitting and weight loss of the coupons made from the 5/16"x3" flat steel strap and those cut from the 20-inch steel main.

The coupons are used in pairs and buried near the bottom of the pipe. (Figure 3.)

Soil taken from the bottom of the

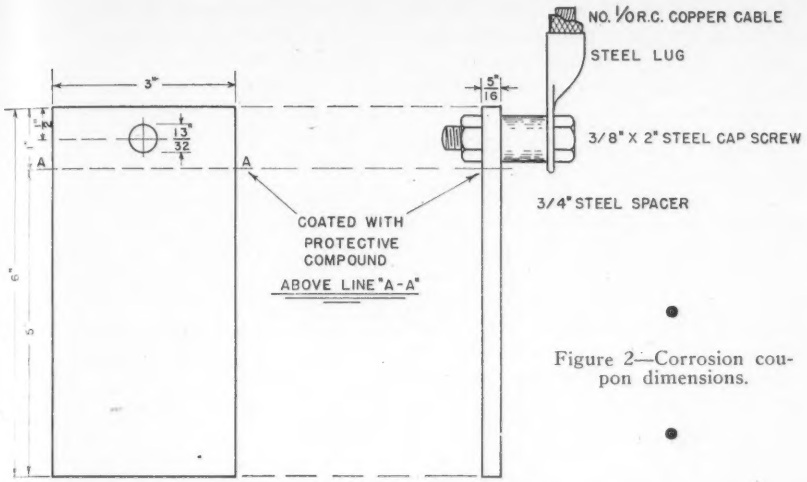



Figure 2—Corrosion coupon dimensions.

excavation is freed of all rocks and pebbles and tightly packed around the plates before the opening is backfilled. The "control coupon," A, is not electrically connected to the pipe. This coupon is attacked by the corrosive action of the soil only, and the pitting and weight loss varies from year to year with the annual changes of rainfall, irrigation or changes in drainage.

The "pipe coupon," B, is electrically connected to the pipe by soldering or brazing, Figure 3, with a No. 1/0 rubber or synthetic insulation covered cable. This coupon is acted on by stray currents and long line currents as well as by the corrosive action of the soil.

All exposed copper-brazed connections, and those portions of the steel plate with the lugs and bolts

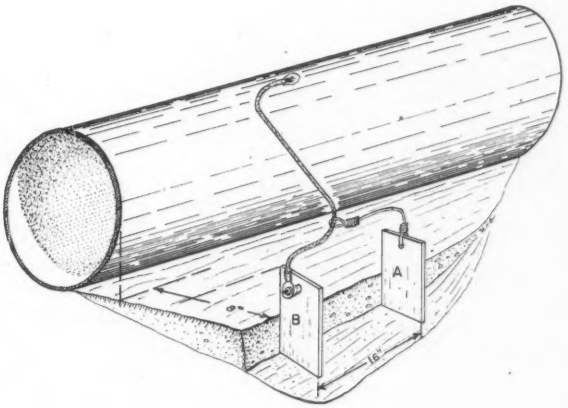



Figure 3 — Method of locating corrosion coupon.

above the line "A - A" of Figure 2 are heavily covered with asphalt, or some inhibitive coating material, to prevent local corrosion on the pipe or coupon.

### Seasonal Changes Considered in Determining Test Period

The corrosion coupons, except in a few special cases, are allowed to remain in the soil for a period of 12 months, and then replaced with a new pair of plates. The 12-month periods are usually terminated in the Fall of the year, and the plates are changed before the Winter rains set in. Later in the year, many portions of the country in which the most corrosive areas are located, are flooded, making coupon changing in many cases difficult, if not impossible.

The time of removal is of considerable importance, since an additional wet or dry season will make it difficult to compare the corrosion of the current period with that of the previous year. This is due to the fact that all wet and dry seasons are not of the same length, nor are the annual rainfall, moisture penetration, or average temperature, always the same.

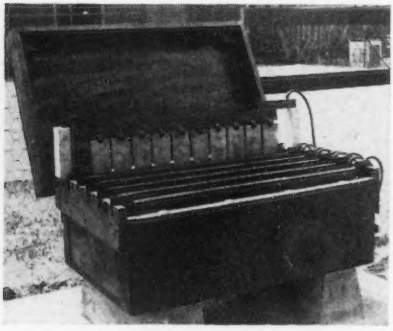


Figure 4—Electrolytic cleaning tank.

The coupons are usually covered with considerable rust and scale after being in the soil for a 12-month period. These corrosion products must be removed and all pits cleaned before the pit depths can be determined.

### Method of Cleaning Coupons

The cleaning is carried out with a minimum of labor by making the rust covered steel plates the cathodes between graphite anodes in a two percent solution of sulphuric acid.[1] (Figure 4.) A direct current of approximately one ampere or more per coupon is passed through the electrolyte, the coupons being allowed to remain in the bath all day or over night. Since the metal coupons are electrolytically protected in the acid electrolyte while the current is flowing, no corrosion of the steel coupons will take place after the adhering oxides are reduced. It is unnecessary to turn off the current or remove the plates from the solution at any definite time.

The coupons, when removed from the cleaning tank, are bright and clean, with only an occasional deep pit requiring additional hand work.

After the plates are removed from the acid solution they are washed in fresh water, dried and rubbed over with an oiled cloth to avoid tarnishing.

### Measuring Pit Depths

The pit depths[2] on the coupons are measured by clamping the plate horizontally in a holder, which is moved on a surface plate under a micrometer gauge as shown in Figure 5. Both sides of the coupon are explored with the gauge and the deepest pit located. No measurements are made at the edges, where

the corners are usually rounded off or destroyed by the simultaneous action of the soil on the two intersecting surfaces of the metal.

The effective area of a coupon exposed to the action of the soil is only 26.82 square inches. The deepest pit found on this area is multiplied by 2.8, to approximate the deepest pit that is likely to occur on the surface of a pipe having over 100 square feet exposed to the soil.[3]

## Putnam's Equation Used to Compute Pit Depth Time

The Pit Depth/Time equation[4] used to reduce the measured pit depth to a one-year time of exposure basis, and to calculate the estimated date of the first failures is the parabolic equation suggested by Putnam.

$P = Kt^n$ in which
P = Depth of pit at end of t years.
K = Initial pit depth at end of first year.
t = Number of years during which pipe or coupon was exposed to the corrosive action of the soil.
n = Exponent which varies between 0 and 1 and is, to an appreciable extent a function of the aeration of the soil; it approaches the lower limit in well aerated soil and unity in poorly aerated soils such as moist clay, moist adobe, swamps, etc.

Since an average pipeline in open country is poorly aerated in Winter during the rainy and flood seasons, and is comparatively well aerated during the Summer months, an average value of $n = 0.5$ is used.

Putnam, experimenting with the 80 soil samples of the Bureau of Standards, found the value of $n = 0.61$,[3] but later considerations showed that the value of 0.5 was sufficiently accurate for all practical purposes.

This exponent will vary with the soil formation and aeration encountered in different localities, but agrees well with the average value of the actual cases of the predictions of the pipe failures.

The equation used for determining the pit depth at any time is therefore,

$$P = Kt^{0.5} \qquad [1]$$

The equation used in reducing the corrosion coupon pit depths to a one year basis, if the actual exposure has been greater or less than 12 months, is,

$$P = \frac{P_t}{t^{0.5}} \qquad [2]$$

in which

P = Max. corrosion coupon pit depth in one year.
$P_t$ = Max. pit depth found on coupon exposed more or less than one year.
t = Actual time of exposure of corrosion coupon, as a decimal fraction of one year.

The pit produced on a corrosion coupon which is placed in the ground for a period of twelve months, is a measure of the average corrosion taking place during the year on a newly installed line, and the pit depth on the coupon will be equivalent to the depth of a pit produced on a pipe during the first year after its installation.

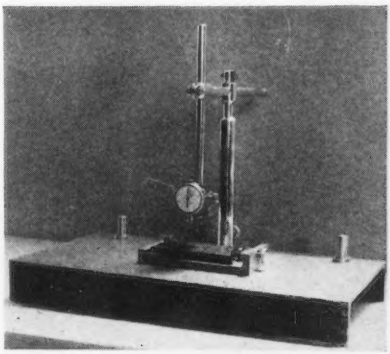


Figure 5—Pit depth measuring plane table.

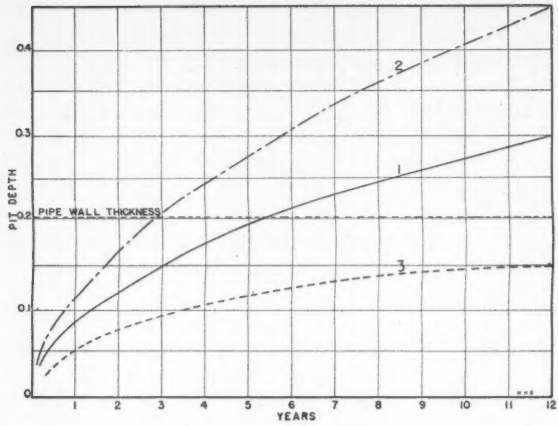



Figure 6—Time pit depth curves for three different soil corrosivities.

If the average annual corrosivity is constant over a period of years, the pit depth will increase at a decreasing rate as shown by Curve 1 of Figure 6.

The intersection of these curves with the line "A - A," showing the pipe wall thickness, will give the expected or theoretical pipe life to the time of the first failure. (Figure 7.)

As a first approximation, the pipe life may be calculated from the pit depth indications given by the first one year corrosion coupon by the equation,

$$L = \left[\frac{T}{2.8P}\right]^2 \qquad [3]$$

in which

L = estimated theoretical pipe life until the first failure in years.
T = pipe wall thickness in inches.
P = maximum corrosion coupon pit depth.
2.8 = constant used to correct for area.

The corrosivity of the soil is seldom constant from year to year, as was assumed in plotting the curves of Figure 6, except in the case of marshes, tidelands and similar locations.

The pitting of the control coupons show that the corrosivity of the soil may vary over a wide range during a period of years.

In determining the actual progress of corrosion in pitting a pipe, and in order to determine the life, or time of first failure of a pipe of known wall thickness, it is necessary to make due allowance for this annual variation of the soil corrosivity, the age of the pipe, and that of the pits existing thereon.

The "increase" in the depth of a pit during any year in terms of the pit depth produced by the soil during the first year of its action on a pipe as shown by the pipe coupon, (the soil corrosivity being constant from year to year) is given by the equation,

$$A = \sqrt{n} - \sqrt{n-1} \qquad [4]$$

A = Activity Factor — increase of pit depth each year in terms of the pit depth produced on a newly installed pipe during the FIRST year.
n = Number of years that have elapsed between the installation of the pipe and the removal of the coupon.

The "Activity Factor," A, for any

year is given in Column 3 of Table 1, or can be calculated or determined by the use of a table of square roots.

The amount that is added to an existing pit during any year is found by multiplying the area-corrected maximum pit depth of the corrosion coupon of that year, by the "Activity Factor" corresponding to the age of the pit, which is usually the age of the pipe since its installation.

### Application of "Activity Factor"

The use of this factor of activity is illustrated by the following examples:

The maximum pit found on a 12-month pipe coupon is 0.075", and the probability is that the deepest pit that can be found on a one-year old pipe will be 2.8 x 0.075" = 0.210". A pit on this pipe developing for eight years before the above coupon was installed will increase in depth during the ninth year only a fraction of the 0.210". Referring to Table 1, the factor for the ninth year is given as 0.172.

Therefore, the increase in pit depth will be:

$$0.172 \times 0.210 = 0.036''$$

If the total depth of the deepest pit on the pipe at the end of the eighth year was 0.314", the pit depth at the end of the ninth year will be:

$$0.314'' + 0.036'' = 0.350''$$

The following two examples will illustrate the method of accumulating the annual contributions to the depth of a pit in a soil of varying corrosivity.

**TABLE 1**

**Increase of Pit Depth Under Constant Soil Corrosive Condition**

| n = Age of Pipe in Years | Activity Factor per Year $A = \sqrt{n} - \sqrt{n-1}$ | Total Pit Depth |
|---|---|---|
| 1 | 1.000 | 1.000 |
| 2 | 0.414 | 1.414 |
| 3 | 0.318 | 1.732 |
| 4 | 0.268 | 2.000 |
| 5 | 0.236 | 2.236 |
| 6 | 0.213 | 2.449 |
| 7 | 0.197 | 2.646 |
| 8 | 0.182 | 2.828 |
| 9 | 0.172 | 3.000 |
| 10 | 0.162 | 3.162 |
| 11 | 0.156 | 3.316 |
| 12 | 0.148 | 3.464 |
| 13 | 0.141 | 3.605 |
| 14 | 0.137 | 3.742 |
| 15 | 0.131 | 3.873 |
| 16 | 0.127 | 4.000 |
| 17 | 0.123 | 4.123 |
| 18 | 0.120 | 4.243 |
| 19 | 0.116 | 4.359 |
| 20 | 0.113 | 4.472 |
| 30 | 0.101 | 5.48 |
| 40 | 0.084 | 6.32 |
| 50 | 0.075 | 7.07 |
| 75 | 0.016 | 8.66 |
| 100 | 0.013 | 10.00 |

**TABLE 2 — CASE 1**

**Corrosion coupon installed when pipe is laid. Pipe wall thickness = 0.203 inch.**

| (1) Age at Pipe Years | (2) Max. Pit Depth on Pipe Coupon | (3) Max. Pit on Corrosion Coupon Corrected for Area (×2.8) | (4) Activity "A" per Year in Terms at First Year | (5) PI/Yr. = Increase in Pit Depth on Pipe (3)x(4) | (6) Total Accumulated Pit Depth | (7) PIT DEPTH Based on 7th Year Low Rate Only | (8) PIT DEPTH Based on 9th Year High Rate Only |
|---|---|---|---|---|---|---|---|
| 1 | 0.024 | 0.067 | 1.000 | 0.067 | 0.067 | 0.059 | 0.174 |
| 2 | 0.031 | 0.087 | 0.414 | 0.036 | 0.103 | 0.083 | 0.246 |
| 3 | 0.031 | 0.087 | 0.318 | 0.028 | 0.131 | 0.102 | 0.301 |
| 4 | 0.038 | 0.113 | 0.268 | 0.030 | 0.161 | 0.118 | 0.348 |
| 5 | 0.036 | 0.102 | 0.236 | 0.024 | 0.185 | 0.132 | 0.389 |
| 6 | 0.022 | 0.061 | 0.213 | 0.013 | 0.198 | 0.145 | 0.426 |
| 7 | 0.021 | 0.059 | 0.197 | 0.012 | 0.210 | 0.157 | 0.460 |
| 8 | 0.032 | 0.090 | 0.182 | 0.016 | 0.226 | 0.168 | 0.491 |
| 9 | 0.062 | 0.173 | 0.172 | 0.030 | 0.256 | 0.178 | 0.521 |
| 10 | 0.040 | 0.112 | 0.162 | 0.018 | 0.274 | 0.187 | 0.549 |

Case 1) Corrosion coupons are installed when the pipe is installed, Table 2.

Case 2) Corrosion coupons are installed on an old line, a number of years after the pipe was installed, Table 3.

The results of the coupon test given in Table 2 are shown graphically in Figure 7.

The pit depth curves, based on the highest and lowest rates of pitting during the seventh and ninth years, as indicated by the coupons of those years only, are shown for comparison in Columns 7 and 8, Table 2. A comparison of these two columns shows the error that may occur in predicting the pipe life when the estimate is based on the indications of the pipe coupon for one year only.

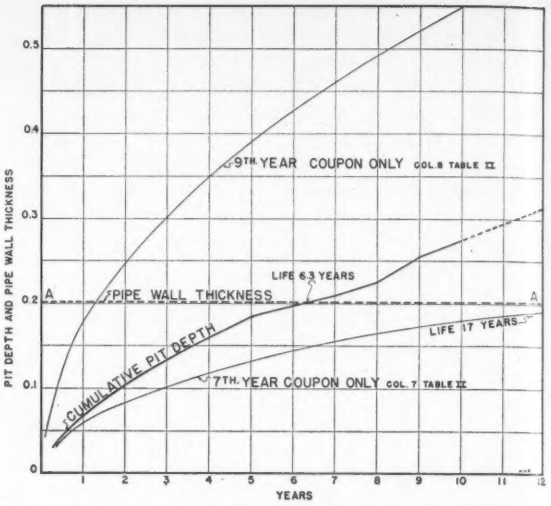



Figure 7—Cumulative pit depth-life time curves. Pipe six inches O.D., wall thickness, 0.203 inch. Installed 1925.

When based on a single dry year of Column 7, the pipe would have failed in eleven years; whereas a similar calculation from Column 8, based on a single wet year, would have indicated a pipe failure in one and one-half years.

The accumulated pit depth indi-

**TABLE 3 — CASE 2**

**Coupons installed later than pipeline. Pipe installed five years before coupons were installed. Coupons available for sixth to tenth years.**

| (1) Age at Pipe Years | (2) Max. Pit Depth on Pipe Coupon | (3) Max. Pit on Corrosion Coupon Corrected for Area (×2.8) | (4) Activity "A" per Year in Terms of First Year | (5) Pi/Yr. = Increase in Pit Depth | (6) Total Accumulated Pit Depth |
|---|---|---|---|---|---|
| 1 | ..... | 0.083 | 1.000 | 0.083 | 0.083 |
| 2 | ..... | 0.083 | 0.414 | 0.035 | 0.118 |
| 3 | ..... | 0.083 | 0.318 | 0.027 | 0.142 |
| 4 | ..... | 0.083 | 0.268 | 0.022 | 0.164 |
| 5 | ..... | 0.083 | 0.236 | 0.020 | 0.184 |
| 6 | 0.038 | 0.106 | 0.213 | 0.023 | 0.207 |
| 7 | 0.036 | 0.101 | 0.197 | 0.020 | 0.227 |
| 8 | 0.022 | 0.062 | 0.182 | 0.011 | 0.238 |
| 9 | 0.021 | 0.059 | 0.172 | 0.010 | 0.248 |
| 10 | 0.032 | 0.909 | 0.162 | 0.014 | 0.262 |
| 5 Yr. Average = | 0.029 | Av. pit 5 yr. based on average =0.083 | | | |

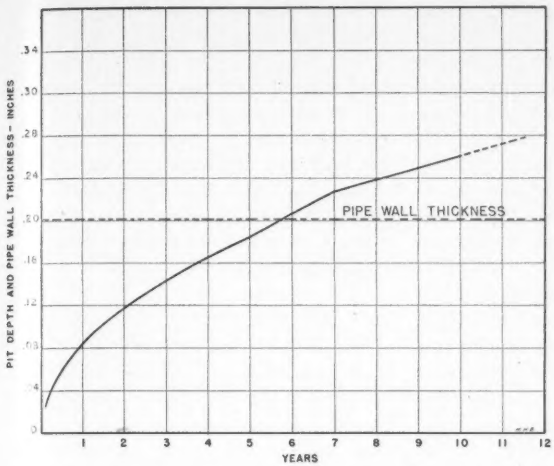



Figure 8—Cumulative pit depth time curve. Pipe six inches O.D., wall thickness, 0.203 inch. Protection S.W.

cated a probable life of six and one-half years.

The intersections of these curves with the horizontal line "A - A," indicating the pipe wall thickness, shows the estimated pipe life, and also shows the wide range and contradictory pipe life estimates that may be obtained as a result of relying on the indications of coupons of a single year only.

The average of the maximum corrosion coupon pit depths for five years in Column 2, multiplied by 2.8 to correct for the area, were substituted for each of the missing first five-year coupon measurements, as shown in Column 3 of Table 3. These values were multiplied by "A" of Column 4, and the results in Column 5 accumulated to give the total pit depths in Column 6 of Table 2.

The results given in Table 2 are shown in Figure 8.

The close agreement of the pipe life predictions of Figures 7 and 8 is partly due to the fact that a portion of the coupon data of Table 2 was used for Table 3, and, further, that the average value which was used in place of the first five years in Table 3 was based on a five-year period. Preliminary estimates of pipe life are usually made as soon as one or two coupons are available, by using Equation 3, but in that case, due to the seasonal variations, the accuracy of the estimates would not be as great.

When corrosion coupon data for a number of years are not available, and the work will not permit the necessary delay of several years to obtain these coupons, a portion of the line may be excavated and examined.

The deepest pit found on 100 square feet of the pipe surface examined, may be used as the starting point, by being placed in Column 6 of Table 2 or 3 opposite the year corresponding to the age of the pipe. The calculations of the pit depth are then continued by accumulating the amount obtained from the corrosion coupons as in the foregoing example.

Logarithmic coördinate paper is a useful medium for plotting the cumulative pit depth curves and graphically determining the pipe life, the pit depth time curve taking the form of a straight line.

In Figure 9, Curve 1, shows the pit depth curve of Column 6 in Table

2 plotted on standard logarithmic paper.

These curves usually approximate a straight line, which can easily be extended to intersect the pipe wall thickness line "A - A," thus giving date of the expected pipe failure.

Any change in the slope or a break in this straight line is indicative of some change in the corrosive conditions surrounding the pipe. Such a changed condition may either increase or decrease the pipe life. Changes in the slope of the pit-depth line may be due to any of the causes enumerated above, such as changes of nearby electric railways, bonds, insulating couplings, drainage of canals, application of cathodic protection, etc.

### Effect Produced by Bonding

Actual example of the effect produced by bonding over a high resistance coupling and of the installation of cathodic protection on the pitting of a pipeline are shown by Curves 4 and 5 of Figure 9.

Curve 3 of Figure 9 shows the effect of the application of electric protection to a line.* The upturn of the curve after four years of protection was due to the breaking of the direct current cables to the pipe and ground electrode during construction work on the highway, and accidental reversal of the polarities when repairs were made. The corrosion coupons gave ample warning of the impending trouble.

### Plowing Land Causes Change

Curve 2 shows the progress of the corrosion on a 20-inch line laid in uncultivated grazing land. The upturn of this curve was the result of plowing, and the plowing and planting of wheat over the line during the war emergency preparedness period in 1939. The breaking up of the soil surface permitted the increased penetration of rain and air down to the pipe level.

Coupons that are removed once a year have undergone a complete cycle of seasonal weather and annual soil corrosivity changes. They are the "guards" or "watchmen" placed

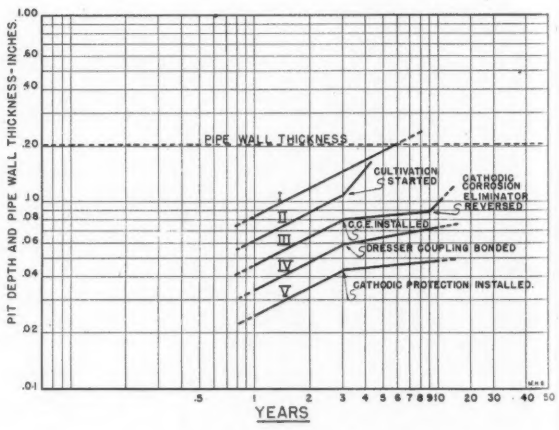



Figure 9 — Cumulative pit depth life time curves. Pipe six inches O.D., wall thickness, 0.203 inch. Installed 1925.

on a pipeline to record the progress of the corrosion, and give notice of accelerated corrosion, which may cause leak failures sooner than previously anticipated.

If the coupon indications are ignored by failure to make the changes and studies at one-year intervals, the failure of the pipe may be the first indication that a serious change has taken place. The annual change of the coupons will avoid many "surprise attacks" on the line, due to pipeline extensions, electric railway changes, irrigation, and other changes; and the saving in repair costs will be greater than the cost of many annual changes of the test plates.

### Long Test Periods Impractical

Pit depth measurements on a coupon buried for a longer period than one year, such as two to five years, may become practically worthless for the purpose of determining the conditions that exist at a given location, as the pit may be caused by:

1) The accumulated effect of a *mildly* corrosive soil over a long period of time, which would indicate no great danger to the pipeline.

2) A *temporary* severe condition that existed at some time in the past and has since abated, thus requiring no mitigative measures at the present time.

3) *Severe* corrosive conditions that have developed *just before* the plate was removed and may continue indefinitely, requiring immediate investigation and the application of mitigative measures.

These three conditions could produce the same size of a pit, but it would not be possible to differentiate between them on one single long-term coupon.

Copies of each of the pit depth curves should be maintained for each station, and the results of each year's observations added. This will serve to draw attention to any detrimental changes that may take place on a line, and permit the matter to be investigated before a failure occurs.

A few illustrations showing the correlation between the pipe life indicated by the corrosion coupons and the actual life as indicated by the time of the first failure, are as follows:

### Test Data Approximate Pipe Life

1) On a new pipeline crossing under the Napa River, a salt water inlet at the north end of San Francisco Bay, the corrosion coupons showed a pipe life of six years. This agreed within six months with the length of life of an older crossing a short distance north of this point on the same stream. The new crossing was given cathodic protection when installed in 1931 and no failures have occurred to date.

2) On Treasure Island, the location of the Golden Gate International Exposition in 1939 and 1940, a corrosion coupon connected to a bare No. 14 gauge sheet steel pipe, indicated a pipe life of 0.49 years. The first leak occurred about four and one-half months after the installation of the pipe. The soil of this island consisted principally of blue mud and sand dredged from San Francisco Bay.

3) Corrosion coupons installed on the eight-inch main south of Salinas, California, indicated a possible pipe life of four and one-half years. The first failure occurred three and one-

half years after the installation of the line, that is, 75 percent of the life expected. This line is in soil adjacent to a heavily irrigated sugar beet field, on which ammonium sulphate is used as the fertilizer.

4) A submarine-crossing under the Oakland Estuary, a salt water channel between Oakland and Alameda, and connected to the Bay of San Francisco, failed in six years. This is the life indicated by coupons placed in the same type of salt-water sand and mud in other parts of the Bay, which were tested with the coupons.

Since most of the highly corrosive areas are given electrical protection when located, or as soon as a failure occurs, there is little opportunity to obtain further data on the theoretical corrosion coupon life versus actual pipe life data in these localities.

Some of the earlier coupons installed on the gas mains failed to give a proper indication of the conditions existing at the surface of the pipe.

Tests made to determine the cause of the discrepancy usually showed that, due to the high quality of the pipe coating, dry conditions of the soil throughout most of the year, improper location, etc., the coupons could not give a true indication, as mentioned earlier.

By applying the data obtained from the corrosion coupons *each year* in the manner outlined in the foregoing pages, it is possible to properly account for the effect of the annual variations in the soil corrosivity and changes in the electrical conditions along a pipeline. The method also eliminates the wide variations in pipe life estimates that are obtained when these estimates are based on the indications of single corrosion coupons only.

* Editor's note: This method of applying protection will be presented in an early edition of Corrosion.

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# Protective Coatings on Bell System Cables*

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PRIOR to 1929, practically all of the underground cables in the Bell system were bare lead-covered cables installed in underground conduit of tile, wood or iron. About that time a new type of construction was introduced, in which the cables were buried in the ground without the use of conduit. Because bare cable thus installed might be subject to severe corrosion, it was necessary to develop suitable protective coatings.

The covering first employed on buried cables consisted of a flooding of asphalt over the lead sheath, followed by a wrapping of paper and a wrapping of jute, to serve as a cushion for two helical wrappings of steel tape. The tapes were then covered with additional jute servings to protect them against abrasion and corrosion. Asphalt was applied between the various layers and over the finished cable, which was also treated with calcimine, to prevent the cable turns from sticking together on the cable reel. This cable was called "tape-armored cable" (Figure 1); and is still used today. The first installation of this type was made between Fort Worth and Cisco in Texas.

In installing such cables, a rooting plow is pulled along the right-of-way with tractors to cut a furrow. This is followed by a cable-laying plow, through which the cable, fed from a reel on a trailer, passes and is laid in the earth. Where the ground is not too hard or rocky, the entire process is performed in one operation. Just before the end of one length of cable is reached, the end of the next length is tied to it with wire bands, and the new length is fed in immediately behind the old length, a marker being placed to indicate the location. Splicing pits are later dug at these points, and when the splices are completed, they are encased in creosoted wood boxes and the earth is back-filled over the box.

The cable route may traverse cultivated fields as well as wooded areas, and does not necessarily follow roads as in the case of the conduit type of construction. The cable and splices are sufficiently deep so

★ A paper presented at the North East Regional meeting of NACE in New York, N. Y., Oct. 24, 1946.

that the field can be worked without interferring with the telephone plant. In general, this installation procedure is followed with all types of toll buried cable.

The purpose of the steel tapes on the tape-armored cable is primarily to prevent damage to the coating by rocks. In locations where there were no large rocks and this degree of protection was not necessary, a new and cheap protective cable was developed, known as "jute-protected cable." This type of coating consists of layers of impregnated paper wrapped over the cable sheath, and floodings of asphalt and jute servings applied outside the paper to protect it from abrasion. Because of its lower cost, this type cable soon found wider application than the tape-armored cable.

### Cloth Substituted for Jute

The next development in cable coatings resulted from the need for a corrosion-protective cable for use in standard conduit construction. For this purpose the jute-protected cable was used, except that wrappings of cloth were used instead of jute over the paper in order to keep the increase in cable diameter to a minimum.

Experience with these coatings has been quite satisfactory, even though they do not maintain high leakage resistance after they have become permeated with moisture. However, coatings having high resistance are advantageous in many locations, particularly where forced drainage is used either on the cable or on a nearby structure. With this in mind, a cable was developed in which the covering consisted of a thermoplastic rubber compound containing reclaimed rubber, clay, resin and a small amount of paraffin. This material is rolled to the desired thickness and applied as a longitudinal strip folded around the cable, which had been previously flooded with a suitable cement. The edges projecting from the seam in the folded strip are then cut off, leaving a longitudinal butted seam in the thermoplastic covering. The cable is then flooded with asphalt and wrapped with a cloth material to withstand the abrasion of handling and installation. The cloth is treated with asphalt and calcimine as in the case of the other types of coatings. Thermoplastic covered cables have been pulled into ducts as well as buried directly in the ground.

### Gophers Cause Serious Damage

In some parts of the country, the installation of buried coated cables of the types described would leave the sheath subject to depredation of certain species of gophers, which chew through the coating and the lead cable sheath. When a cable is to be used in a location where such gophers exist, jute protected and thermoplastic covered cables are made in which a wrapping of a thin steel "gopher tape" is incorporated in the coating (Figure 2). In the case of jute protected cables, gopher tapes are placed over the paper wraps before applying the final jute wrapping. On thermoplastic covered cable, the gopher tape is placed next to the cable sheath after it has been flooded with thermoplastic cement. Experience with these gopher protected cables has shown that when the covering over the tape has been removed by gophers or from other causes, the thin steel tape usually rusted

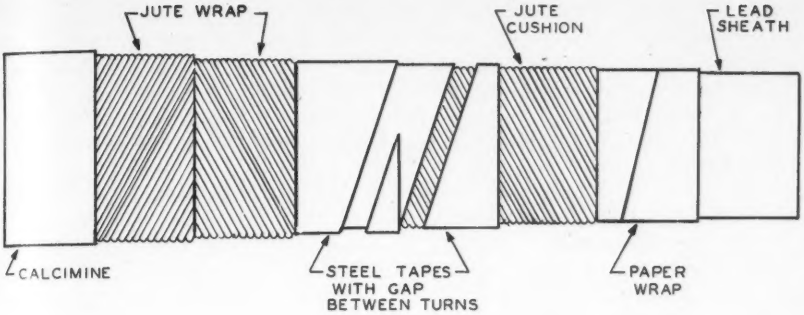


FIG. 1 TAPE ARMORED CABLE

through in a short time. Some modification in design is contemplated on cables manufactured in the future. However, there has been no case to date where gophers caused sheath damage where the tapes had rusted through.

### Buried Cables Create Lightning Problem

The use of buried cables created a lightning problem which had not seriously affected cables in conduit. Where lightning is severe, burns on the cable have resulted from lightning strokes to earth near the cable. Since buried cables have been used largely on long toll routes, interruption of service over the cables is a serious matter. In order to help protect against lightning troubles, bare copper shield wires have been plowed in the ground with the cables to provide additional conductivity in the earth path.

The latest type of covered cable to be installed is copper jacketed (Figure 3). It was developed to minimize lightning troubles as well as corrosion troubles on the cables. The cable is covered with two layers of thermoplastic material, each somewhat thinner than the material used on the previous single layer thermoplastic covered cable. The double layer reduces greatly the possibility of foreign matter in the thermoplastic material, causing a weak point in the dielectric strength. Also, lapped seams are now used instead of butt seams; and by placing the seams 180 degrees apart, the possibility of dielectric breakdown at the seams is greatly reduced.

### Corrugated Metal Used to Gain Flexibility in Handling

Over the two layers of thermoplastic, which are cemented to the sheath and to each other, a flooding of asphalt is applied, followed by a wrapping of cloth and a copper jacket. The jacket consists of a strip of copper, with crosswise corrugations, and is folded around the thermoplastic allowing an overlap of about three-fourths inch. Corrugated metal is used in order to allow flexibility for reeling and unreeling the cable.

After flooding with asphalt, the copper is wrapped with a cloth ma-

terial, to enable it to withstand abrasion and to hold the copper in place, at least until the cable is placed in the ground. Cables with this kind of covering are now being installed from Washington, D. C., to Los Angeles, California.

### Use of Dissimilar Metals Poses Question

The use of steel tapes, copper-shield wires and copper jacket raised the question of the possibility of corrosion resulting from contact between these metals and lead in the earth. The steel tapes of tape-armored or gopher-protected cable are bonded to the sheath at each splice. However, these metals are not far apart in the electrochemical series, and therefore galvanic action should not be severe. Furthermore, steel is generally anodic to lead in solutions having a pH lower than about ten, which includes practically all soil electrolytes, so that while some corrosion may occur on the steel tapes, the more important lead cable sheath is not appreciably affected by the couple action. This has been substantiated by field experience and laboratory immersion tests.

### Overcoming One Disadvantage Causes Another

The use of copper shield wires or copper jacket appeared to present a more serious couple hazard than did the use of steel tape. Since copper is considerably more noble than lead, the copper-lead couple could result in rapid corrosion of the lead.

The best practice for control of lightning trouble is sometimes contrary to the best practice for prevention of corrosion. For example, bonding the shield wires to the cable sheath provides better lightning protection but sets up a possible lead-copper couple detrimental to lead.

After evaluating the relative merits and hazards, it was decided to bond the shield wires to the sheaths of jute protected cable. With copper-jacketed cable the question again arose, and so far the jacket has not been regularly bonded to the sheath, but this practice is still subject to change. It is conceivable that accidental contacts between jacket and sheath may occur but it is felt that the insulation between them will prevent any serious corrosion of the sheath.

### Field, Laboratory Tests Conducted During Development of Coatings

Throughout the development of these coatings, tests were conducted both in the laboratory and in the field. In the field burial tests, many of the cables were specially designed so that the protection offered by the component parts of the coatings could be separately evaluated. The soils in which these tests were conducted included common clay, salt marsh, acid muck, and white alkali. In carrying out these tests, a number of samples of each design were buried at each location so that some

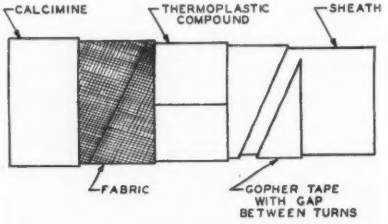


FIG. 2 GOPHER PROTECTED THERMOPLASTIC COVERED CABLE

could be removed periodically and dismantled for examination. Concurrent with these special field burials, some cable samples were placed in trial installations in order to follow their performance under conditions of practical use.

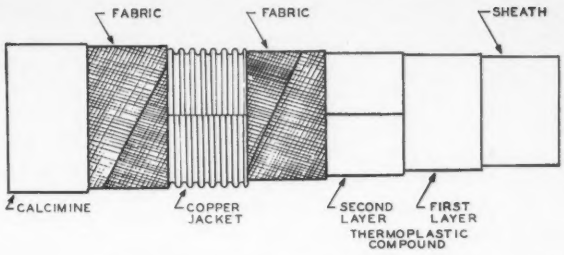


FIG. 3 COPPER JACKETED CABLE

Field tests revealed that cables covered with a thermoplastic rubber compound maintained the highest leakage resistance, and were least affected by corrosion. The protection is best when a suitable bonding agent is used, so that the adherence of the compound to the lead is strong. This type of protective coating is effective because it is impervious and prevents electrolyte from coming in contact with the lead sheath. Because of its higher cost, its use is restricted to locations where a high leakage resistance is desired. Where this degree of protection is not necessary the use of jute or fabric covered cables is indicated.

### Pitch Improves Protection of Fabric-Wrapped Coatings

Tests of jute or fabric-covered cables have shown that a very considerable portion of their protection is obtained through the use of a first coating of asphalt or coal tar compound, which adheres to the lead, covers it completely, and remains soft and tacky. The use of paper wrappings over the compound has proved an expedient and satisfactory method of maintaining a complete and adherent envelope of compound around the cable. The wrappings of jute or fabric, which are placed over the paper, are impregnated and flooded with asphaltic or coal tar compound and serve primarily as protection against physical damage to the undercoatings of paper and compound.

### Attack Insignificant After Nine Years' Exposure

The leakage resistance of these coatings is quite high initially but drops off materially after the coatings have become saturated with soil electrolyte. Nevertheless, the coating serves to maintain a uniform electrolytic environment around the cable sheath. Because of this, the corrosion which occurs is uniform and not serious.

An inspection of jute protected cables after nine years in the test burials showed that the lead sheath had undergone either tarnishing, or a mild form of surface attack, which was too slight to cause any significant effect on the life of the sheath. It was also found in these tests that deterioration of jute buried in soil is not prevented by the use of asphaltic compounds or coal tar derivatives as jute saturants or flooding materials. In some cases, the jute

wrappings were rotted to such an extent that they could not be removed intact, but the saturants and flooding materials kept the wrapping in place; and the combination still effectively protected the sheath against corrosion.

Impregnated and flooded jute coverings applied over steel tapes materially retard corrosion of the tapes, but do not eliminate it. However, the rusting which does occur is usually so sufficiently scattered it does not seriously impair the utility of the tapes.

As might be expected, use of thermoplastic rubber compound over steel tapes offers considerably more protection than jute or fabric wrappings, provided the coatings are not attacked by gophers.

Among the laboratory tests conducted was one in which the effect of externally applied potentials on the behavior of corrosion protected cable was studied by maintaining test cables at neutral, positive, and negative potentials (ranging from 0.0 to 6.0 volts) in dilute sodium chloride solutions. It was found that under neutral or negative conditions the lead sheath underwent only a surface discoloration, while under high negative conditions, the coating lost its adherence and could easily be stripped from the cable. The electrolyte which accumulated on the sheath was alkaline in reaction, which probably accounts for the loss of adhesion. At a potential of about —6.0 volts, blisters formed between the sheath and the coating, probably due to accumulation of hydrogen. Under positive conditions, light etching of the sheath occurred at potentials as low as 0.25 volt. At higher potentials (6.0 volts) some pitting and formation of lead dioxide occurred. The adherence of the coating under positive potential conditions was considerably better than under negative conditions.

Laboratory tests were also conducted on cables in which steel tape armoring was incorporated. Though intended as protection against damage by rocks or gophers, it was found the tapes also exercised a shielding effect against anodic corrosion of the lead sheath. A small hole was made in the thermoplastic coating of a cable having steel gopher tapes, and the cable was maintained at a positive potential in a dilute electrolyte. Under these conditions the steel tape first became perforated, but the corrosion then spread radially thereby increasing the exposed area of sheath. The total anodic area (steel and lead) ultimately exposed by this process was much larger than the area of the original hole in the thermoplastic coating, thus making the current density on the sheath low, and the resulting corrosion less serious. In a similar test, with cables having no steel tapes, a severe deep corrosion pit formed in the sheath directly under the hole in the thermoplastic.

Lead has long been regarded as the ideal sheathing material because of its ductility, flexibility and imperviousness to moisture. The rising demand for cable and the growing world scarcity of lead are combining to force the use of thinner lead sheaths and the search for other forms of sheathing. Reduction of sheath thickness, of course, increases the emphasis on the value of protective coatings.

# Anaerobic Corrosion of Iron in Soil*

*By R. L. Starkey and K. M. Wight*
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ONLY RELATIVELY recently has the economic importance of anaerobic corrosion of iron and steel been realized. The process was first recognized by Von Wolzogen Kühr in 1934, in Holland. Since then its occurrence has been found to be world wide.

This paper deals with the anaerobic corrosion of iron and steel structures buried in soil. Both cast iron and steel are susceptible to anaerobic corrosion. Frequently, aside from the usual attack, when the corrosion of steel is severe, many pits are formed close together; these fuse to produce large corroded areas. Such a condition is known as slab corrosion or slabbing.

## Bacteria Causing Anaerobic Corrosion

The corrosion process itself is caused by microorganisms known as sulfate-reducing bacteria, one of the most common being named *Sporovibrio desulfuricans.* They are small curved cells varying greatly in size and shape but with an average size of 1 by 4$\mu$. Frequently the cells have a spiral shape.

The bacteria were discovered by Beijerinck in 1895 and named *Spirillum desulfuricans.* They were subsequently given various other generic names such as *Microspira, Vibrio, Desulfovibrio,* and *Sporovibrio.*

Four of the important conditions necessary for growth of sulfate-reducing bacteria are favorable pH, absence of oxygen, adequate amounts of sulfate, and adequate amounts of other nutrients. The fourth condition will be amplified later in this discussion.

It was found that the bacteria could grow at any pH between 5.5 and 8.5. Irrespective of the initial pH of the culture media, the final pH was close to 7.0 in all cases where there was bacterial growth.

The degree of aeration or the oxidizing or reducing intensity of the substrate in which corrosion takes place can be expressed as the redox potential ($E_h$, or oxidation-reduction potential). The redox potential

*Condensation of the paper Anaerobic Corrosion of Iron in Soil, R. L. Starkey and K. M. Wight, with particular consideration of the soil redox potential as an indicator of corrosiveness. Report of Distribution Committee of AGA. 108 pp. (1945).

of the substrate must be low in order for reduction of sulfate to take place. The relations between this factor and anaerobic corrosion are considered in detail.

In the metabolism of *Sporovibrio desulfuricans* the sulfate acts as the hydrogen acceptor and becomes reduced to sulffide. Organic nutrients act as hydrogen donors for this reduction. During the course of the studies, evidence was obtained that the sulfate-reducing bacteria can also utilize molecular hydrogen as a hydrogen donor. This provides additional evidence of the ability of the bacteria to depolarize the system and effect corrosion according to the process proposed by Von Wolzogen Kühr.

## Mechanism of the Process of Microbiological Anaerobic Iron Corrosion

Microbiological anaerobic iron corrosion is believed to be the result of the following reactions:

$$8H_2O \rightleftarrows 8H^+ + 8OH^-$$
$$4Fe + 8H^+ \rightleftarrows 4Fe^{++} + 8H \quad \text{Anodic solution of iron}$$

$$H_2SO_4 + 8H \rightarrow H_2S + 4H_2O \quad \text{Depolarization}$$

$$Fe^{++} + H_2S \rightarrow FeS + 2H^+$$
$$3Fe^{++} + 6OH^- \rightarrow 3Fe(OH)_2 \quad \text{Corrosion products}$$

The summarized reaction would be:

$$4Fe + H_2SO_4 + 2H_2 \rightarrow 3Fe(OH)_2 + FeS$$

The principal products are iron sulfide and ferrous hydrate. The iron sulfide is black and the ferrous hydrate white. The process is electro-biochemical. The bacteria perform the depolarization. Evidence for the utilization of molecular hydrogen by sulfate-reducing bacteria has been previously cited.

## Detection of Microbiological Anaerobic Iron Corrosion In Soils

Most of the report is devoted to experimental results pertaining to a method of detecting microbiological anaerobic corrosion in soil *in situ*.

In arriving at a simple method of detecting anaerobic corrosion, four factors were taken into consideration. These factors were those influencing anaerobic corrosion, namely: pH, redox potential, sulfate, and other nutrients such as organic matter. It had been found earlier by Hadley and later in these investigations that there is no correlation between the amount of sulfate in the soil and the intensity of anaerobic corrosion.

Soil pH and $E_h$ are easily measured and were found to be useful criteria of incidence and severity of corrosion in the field *in situ*. The pH is easily measured by means of a glass electrode—a method well known. The redox potential is measured by means of a platinum electrode with a calomel cell as the reference half cell.

Laboratory experiments were performed to determine the extent of changes in the redox potentials of culture media supporting growth of sulfate-reducing bacteria, as well as of soils under conditions both favorable and unfavorable to development of these microorganisms. These results gave indication of the extent of potential changes likely to be encountered in the field.

In a culture medium, the $E_h$ dropped sharply from about 300 mv

to —200 mv during growth of the bacteria. When there was metallic iron in the medium, the redox potential of the substrate became as low as —400 mv. The $E_h$ of media containing metallic iron was unaffected by growth of the organism.

Laboratory studies with soils indicated that there was no appreciable change in the soil redox potential when organic matter underwent decomposition under aerobic conditions; whereas there was a pronounced decrease in the potential when organic matter decomposed in water-logged soils.

In addition to direct measurement of the soil $E_h$, the following determinations were made: the $E_h$ of acid extracts of soil, the $E_h$ of alkaline extract, the reducing capacity of the acid extracts as determined by potentiometric titrations with an oxidizing agent. Only the last of these three provided information of value. Potentiometric titrations of acid extracts were useful as a supplement to the direct measurements in that they indicated the relative amounts of reducing materials in the soils.

Preliminary field tests made at sites on the property of the Susquehanna Pipe Line Co. showed correlations between the soil redox potential and the severity of anaerobic corrosion. These results indicated that measurements of the soil pH and $E_h$ might prove useful as criteria of soil corrosiveness. However, the laboratory equipment was not suitable for field use. Furthermore, tests on soil samples were unsatisfactory since there were frequently changes in the soil due to sampling and storage between the time of sampling and making the determinations.

In order to simplify the measurement of soil $E_h$ and pH in the field and also increase the accuracy of the results, an instrument was constructed by means of which the measurements could be made *in situ*. This consisted of two four-foot pastic tubes, one fitting inside the other. The inside tube contained a vent tube and four electrodes consisting of a calomel electrode, a glass electrode, and two platinum electrodes. Openings were present in the walls of both the inside and outside tubes at the location where the electrodes were placed. When these openings coincided, the electrodes were exposed. The wires from the electrodes ran up through the tube; these were connected to a potentiometer circuit wherever $E_h$ and pH measurements were made.

The instrument was operated as follows: The soil was first loosened with a bar. Then the instrument carrying the electrodes was pushed into the soil to the desired depth. The openings of the inside and outside tubes did not coincide; hence the electrodes were concealed as the instrument was lowered into the hole. At the desired soil depth the tube was rotated until the openings in the two tubes coincided and exposed the electrodes.

In order to operate the instrument successfully, a new method of cleaning the platinum electrodes was devised. The electrodes were first washed free of soil material, after which they were treated with a solution containing five percent acetic acid and five percent synthetic deter-

gent, an alky aryl sulfonate having the trade name Nacconol NRSF. This treatment was followed by washing with distilled water, after which the electrodes were immersed in 10 percent hydrogen peroxide and then washed with distilled water. Both immersions were not more than 15 seconds in duration.

As a result, field studies could be made along pipelines in an attempt to correlate soil pH and $E_h$ with the incidence and severity of anaerobic corrosion where the extent of anaerobic corrosion was known.

As a result of field studies, the following scale was adopted as a basis of classifying soils as to corrosiveness:

| Redox Potential Of Soil | Classification of Anaerobic Corrosion |
|---|---|
| Below 100 mv | Severe |
| 100 to 200 mv | Moderate |
| 200 to 400 mv | Slight |
| Over 400 mv | None |

This scale is arbitrary and might well be modified as more information becomes available. Soils with reactions more acid than pH 5.5 or more alkaline than pH 8.5 were considered to be unfavorable for anaerobic corrosion. The severity of corrosion estimated from pipe inspection was judged by the depth of the pits, the number of pits, and thickness of corrosion products with consideration for the age of the pipe.

Numerous field tests were made to determine the validity of the presumption that there was a correlation between soil redox potentials and corrosiveness. Sites were selected where there were no stray currents, no consumer gas in the soil coming from breaks in the main, and no seasonal variations in soil conditions such as drying of the soil in the summer due to low rainfall.

These sites were located on the properties of the following six companies: Susquehanna Pipe Line Co., Philadelphia, Pa.; New York and Richmond Gas Co., Staten Island, N. Y.; Brooklyn Union Gas Co., Brooklyn, N. Y.; Public Service Electric and Gas Co., New Brunswick, N. J.; Consolidated Gas, Electric Light and Power Co., Baltimore, Md., and Philadelphia Electric Co. of Philadelphia, Pa. Through the cooperation of these companies it was possible to make the soil measurements at locations where the corrosiveness of the soils was known, or could be determined by inspection of the buried pipes after the measurements of soil $E_h$ and pH had been made.

In addition to tests for $E_h$ and pH, and inspection of the pipe, observations were made at each site of soil drainage, soil characteristics, and topography. Some supplementary soil measurements were made on soil samples collected at some of the sites. These included measurements of the potentials of acid extracts of the soils and determinations of the reducing capacities of the soils by potentiometeric titrations of the acid extracts with potassium permanganate.

Twelve of the 48 sites, where there was a minium of complicating corrosive factors, were severely corrosive. The agreement between the classifications of soil corrosiveness, according to pipe inspection and to the soil $E_h$ was perfect for seven of the twelve sites. For four of the remaining five, corrosion was slightly milder than that indicated by soil

$E_h$. At the remaining site the $E_h$ was very low, indicating severe corrosion but the corrosion was only slight. One or two other cases such as this were encountered. The significance of very low soil potentials and their relation to the severity of anaerobic corrosion remains to be established.

There were 15 sites where corrosion was moderate according to the soil $E_h$. There was perfect agreement between soil $E_h$ and corrosion as revealed by pipe inspection at seven of these sites, fair agreement at four, and poor agreement at the other four. In virtually every case where there was only fair or poor agreement between the classifications of corrosion, more severe corrosion was indicated by soil $E_h$ than that actually shown by pipe inspection. The reasons for lack of agreement in certain cases were not evident. Possibly at some sites there might have been seasonal variations in soil conditions. It was not possible to tell whether such was the case since the sites were visited only once.

### Corrosion Slight at Four Sites

There were four sites encountered where corrosion was only slight as judged by soil $E_h$. Agreement was perfect for two of the sites and fair for the other two. Here again the agreement between soil $E_h$ and severity of pipe corrosion was remarkably close for these borderline soils.

For the 11 non-corrosive soils, correlation between soil $E_h$ and actual corrosion was perfect.

In summary, corrosiveness was correctly estimated by the soil tests in 67 percent of the cases and estimated with a fair degree of accuracy in 23 percent. In only 10 percent of the cases were the predictions poor. The high degree of correlation between the soil $E_h$ and corrosiveness indicated that the soil measurements could serve as a basis for estimating severity of anaerobic corrosion.

There were a number of sites that were of particular interest because of the unusual soil conditions. It was clearly established at these sites that the soil $E_h$ was a function of the aeration of the soil water.

At a few sites abnormalities were encountered, as where the metal became cathodic due to stray currents. Here there were no consistent correlations between soil $E_h$ and the severity of anaerobic corrosion.

### Seasonal Changes Have Bearing on Degree of Aeration

Seasonal changes in the level of the soil water table resulted in variation in the degree of aeration in certain soils. In cases where these changes occurred, during wet periods the soils were poorly aerated and anaerobic, had low redox potentials, and were nearly neutral in reaction; during dry seasons the soils at pipe depth had high redox potentials, became dry, well aerated, and fairly acid in reaction.

Consumer gas in soil interferes with measurement of the soil redox potential. When gas was introduced into aerobic soils, the potentials dropped rapidly to values typical of anaerobic soils. Similar but less persistent changes in $E_h$ were produced by hydrogen gas.

Anaerobic corrosion was most severe in wet poorly drained soils which had low redox potentials between 0 and 100 mv. The soils had reactions close to neutrality and gen-

erally contained iron sulfide. Soils with moderate corrosion had somewhat higher redox potentials between 100 and 200 mv. Anaerobic corrosion was not encountered in aerobic soils which had redox potentials greater than 400 mv, except where conditions were complicated by such factors as seasonal variation in soil conditions or stray current electrolysis.

No correlation was noted between soil texture and severity of anaerobic corrosion. Soil drainage was a better index of corrosiveness than soil texture. Anaerobic soils of coarse texture were always near rivers, lakes, swamps, or the ocean, which kept them saturated with water at pipe depth. Heavy soils that were poorly drained and anaerobic were not confined to locations near bodies of surface water. The development of anaerobic conditions in poorly drained soils by stagnation of water provides conditions favorable for anaerobic corrosion. In cases where the soil water was in motion, however, the soil redox potential was generally high and there was no anaerobic corrosion.

## Resistance of Some Pipe-Wrapping Materials to Decomposition in Soils

The potentials of the acid extracts of the soils showed no consistent correlation with the severity of anaerobic corrosion. The reducing capacities of anaerobic soils were much greater than those of aerobic soils, but no close quantitative relationship was found between the degree of soil reductiveness and the value of the reducing capacity. The reducing capacities of sands and peats were relatively low, irrespective of the degree of the reductiveness of the soil or the severity of corrosion.

Some experiments were performed in order to observe the susceptibility of cellulosic compounds, particularly cellulose acetate, to attack by soil microorganisms, but not with the idea of testing the product of any particular concern. No tests of the durability of either creosote or bitumen were made.

Each pipe wrapper consisted of a cellulose acetate sheet, a sheet of fabric or asbestos, and wax containing ferric oxide impregnating both of these and holding them together as a thin wrapper. Each was buried in soil for a period of several months under aerobic and anaerobic conditions. Some were removed after six months; the rest, after a year.

## Breakdown Different Under Aerobic, Anaerobic Conditions

The cellulose acetate, which made up only a small part of the tensile strength of each wrapper, was resistant to decomposition. The rest of the wrapper, however, was attacked by soil microorganisms. The nature of the breakdown appeared to be different under aerobic and anaerobic conditions.

It is possible that as a result of the weakening of the wrapping materials by decomposition, there would be a tendency for the wrappers to break away from the pipe with shifting of the soil by heaving or settling. Hence one might expect the pipe to become exposed in time, after microbial attack resulted in complete disintegration of the wrapping materials.

# Laboratory Evaluation of Corrosion-Resistant Pigments and Vehicles*

*By Harold Zahn*

Research Laboratories, National Lead Co., Brooklyn, N. Y.

LABORATORY STUDY of inhibitive paints and pigments, as regards protection of base metal so covered, can be classified into two general methods. One method might be considered as a simple "go, no-go" type of test and the other depends upon analysis of forces in the paint-metal system working for or against anti-corrosive conditions. Laboratory study of inhibitive paints and pigments has been severely handicapped in that corrosion processes are very complex and reliable laboratory techniques for anti-corrosion evaluation of paints are almost non-existent.

It has been generally necessary to rely upon time consuming exposure tests for actual evaluation of paint's worth or, by use of accelerated test equipment, determine trends as to a given paint's effectiveness. Both mentioned tests tell little beyond how long the test panel lasted before failure occurred — failure evidenced by visible accumulation of corrosion product. The test results were arbitrarily analyzed as indicating acceptance or rejection of the tested paint.

Because of the complicated nature of corrosion, which is greatly influenced by environment, an exposure at one location cannot be relied upon as a means to evaluate the same paint in another location. Accelerated tests do not duplicate any one environment entirely and therefore, because of their exaggerating one or more factors, can only be used in guarded qualitative analysis.

Perhaps the greatest disadvantage of accelerated and actual exposure tests to the laboratory worker, aside from the time element, is the failure of the two test methods to indicate what is occuring under the paint film at the metal surface upon exposure of specimen. What factor or factors were dominant in the degree of protection obtained or what factors controlled breakdown cannot be accurately determined from such data. Visual evidence of film deterioration and failure does not indicate whether failure occurred spontaneously or progressively, neither will such observations permit quantitative study of factors contributing to or detracting from the protective action of a paint film.

The following discussion covers certain tests made in our laboratory with a technique first suggested by Burns[1] and his co-workers for the following of corrosion processes as they occur under a paint film. It per-

*A paper presented before Symposium on Corrosion Resistant Paints, Brooklyn Polytechnic Institute, Brooklyn, N. Y., May 4, 1946. Reprinted by permission from Paint, Oil and Chemical Review, Sept. 5, 1946.

mits following of a non-corroding or corroding state of the base metal, from time of exposure to a given set of conditions, to any such time as the test may be considered complete, but it is not a rate study.

The method has been found promising because it is sensitive to factors known to affect paint field performance, and it reflects the state of underlying metal from time of test exposure to time of corrosion activity without reliance upon visual failure.

### Reliable Laboratory Determinations On Paint

The technique does not answer all questions regarding an inhibitive paint's effectiveness but, together with other physiochemical methods, it is believed that rapid, reliable laboratory determinations on paints can be made.

This method does not permit quantitative evaluation of any one factor involved in the corrosion system. The data reflect the cumulative action of all factors in the system. However, by control of one or more of the variables, their effect on the cumulative result can be readily determined.

The technique is essentially based upon the potential relationship of steel to hydrogen as regards corrosion of the steel or lack of corrosion attack. Potential values positive to hydrogen, according to convention, indicate that the metal is not corroding or is in a passive state. Metal potentials negative to hydrogen reflect a corroding condition. The validity of this analysis has been checked with several hundred determinations in that, with the recording of negative potentials, corrosion has always been found below the paint film and never found with recording of positive potential values where period of test is in accord with rate of corrosion. Attention may be called here to the fact that this particular technique records what is happening as regards corrosion under the paint film on the metal surface and does not depend upon visible, physical manifestations of failure. Visual evaluation of paint worth does not make clear whether such failure occurred spontaneously or progressively. Potential-time curve analysis does permit study of how failure occurred.

### Data Indicate Sensitivity of Test Method

The data presented here are not intended to evaluate or show the relative merits of any pigments, vehicles or metal surface preparation involved in the study. The data indicate the sensitivity of the test method towards factors known to affect field paint performance.

All measurements made for this study were obtained with a Leeds and Northrup Vacuum-Tube Potentiometer or a Weston Vacuum-Tube Voltmeter calibrated for d.c. use, and all tests were run in duplicate.

Test cell, panel and reference cell arrangements used are shown in Figure 1.

A saturated calomel reference electrode was used and data were plotted on a hydrogen reference basis.

The glass cell mounted on the paint panel was 15 mm in diameter, and 5 cc of test solution was contained within the cell itself, exclusive of solution in bridge or reservoir. By applying suction to the side

area of the test cell, solution was drawn into the cell from the reservoir and voltage readings could be taken as the circuit was completed through the bridge.

Paint films were applied by doctor blade for purposes of obtaining uniform film thickness. A thin, one-coat application was made unless otherwise indicated.

### Steel Panels Used in "As Received" Condition

All steel panel material was of one lot SAE No. 1010, cold rolled strip (1/32-inch thick) and the material used in the "as received" condition, except for solvent cleaning or preparation of surface as required for the various tests.

In this study, two pigments designated A and B were used. The chemical nature of these two pigments will not be discussed because results given in this paper are not intended for use in comparing the different pigments and secondly a 24-hour test period, as used in obtaining most data presented here, is not always adequate to evaluate fully a paint or pigment's value. Some paints require test periods extending into hundreds of hours. A 24-hour test period is, however, believed adequate to show the sensitivity of the test method to some of the common variables encountered in field paint practice.

Two vehicles of widely different character were employed in the tests described here. Again, since the purpose of the test was to determine sensitivity of test method to vehicle change and was not intended to compare vehicles, the vehicles will, hereafter, be referred to as vehicle I and vehicle II.

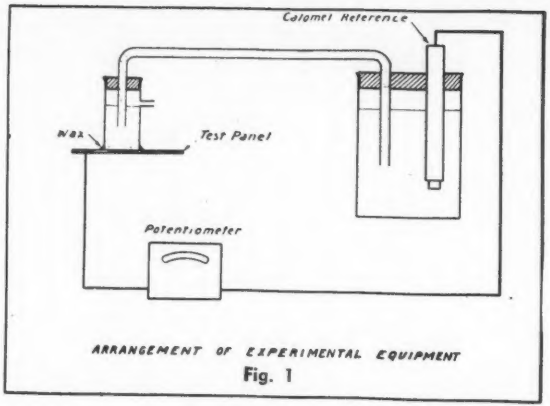
To determine the feasibility of using a single stock supply of the same paint for tests which covered a time period of several months, tests were first made to determine effect of paint age on potential-time curves. For this purpose, two paints using vehicle I were prepared, one with pigment A and the other with pigment B. Tests were conducted on these paints when freshly mixed (about one hour before application to the steel test panels) and with paint which had been mixed about one year previous to application. For each type of paint, the curves obtained showed practically no difference so, for the majority of tests reported here, the vehicle I paints were of a single batch mixed at the start of experiments.

Paints made with vehicle II were prepared approximately 48 hours before application. Shelf life effects were not determined on these paints since only one series of tests were run.

### Development of Technique

On making initial potential-time tests, it was found difficult to obtain reproducible results. Thickness of film measurements established that uniform films were being used and the cause of difficulty lay elsewhere. Recognizing that porosity of film is important in any type of test and one difficult to control, painted panels were tested electrographically for porosity prior to test.

By use of this porosity test method, suitable test zones free of pores could be chosen for the potential-time test, which eliminated the variable of porosity. A further advantage of the method lay in being able to mark areas suitable for test prior to




ARRANGEMENT OF EXPERIMENTAL EQUIPMENT

Fig. 1

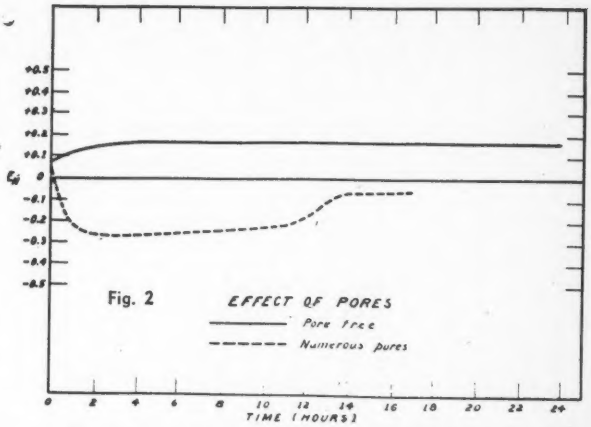



Fig. 2

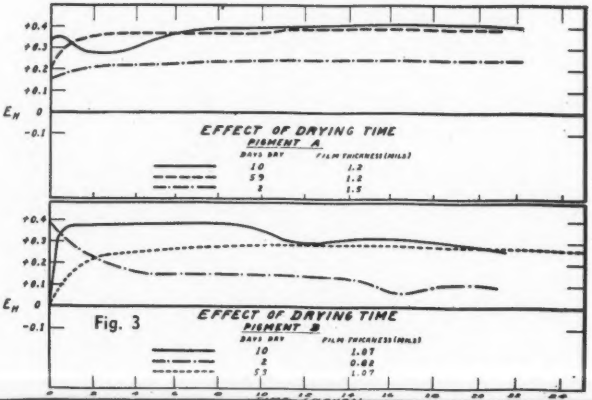



Fig. 3

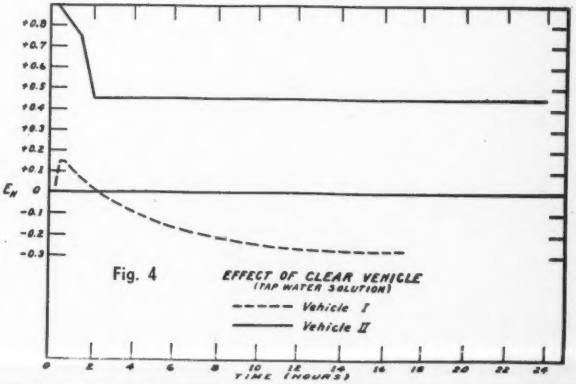



Fig. 4

cell mounting, and then measuring film thickness at actual test zone instead of using thickness values obtained by averaging large panel areas. Film thicknesses were determined using a Magne-Gage instrument. Figure 2 illustrates how pores in the paint film can lower the potential of a test panel as compared to the potential of a pore free film.

### Effect of Drying Time

Field tests have shown how important drying time prior to exposure can be and several tests were made to determine how potential-time results would be affected by changes in drying time prior to test.

For discussion here, drying time effects upon pigment A and pigment B in a common vehicle will be presented. Pigment A films were dried for 2, 10 and 59 days prior to test. Pigment B films were dried 2, 10 and 53 days before test. Tap water was the contact solution employed for these studies. (Figure 3.)

Films of both pigment A and B showed better performance with increased drying time. This order of effectiveness has been found to carry through on test periods involving more than 24 hours. It is apparent that a paint analysis by this technique must consider drying time as a factor.

### Effect of Vehicle

Because the vehicle is recognized as an integral part of the protective performance obtained from paint, various vehicles were investigated.

Vehicles used in these experiments were first tested in the clear unpigmented states, as shown in Figure 4. The considerable variation in curves obtained was not unexpected in view of their different compositions. The straight line potential value obtained with vehicle II is of importance not only in demonstrating the sensitivity of the test method towards change in vehicle, but also serves to emphasize the importance of having test periods of more than 24 hours in some cases. Potential curves for certain pigments incorporated in vehicle II fell directly on the curve obtained for the clear vehicle over a 24-hour test period. Therefore, a 24-hour test is definitely inadequate as regards the evaluation of some pigments in this vehicle.

### Physical Changes Occur in Few Hours

Figure 5 illustrates effect of vehicle change using a common pigment. It will be noted that vehicle I showed definite response to pigmentation but vehicle II, plus pigment, was unchanged from the unpigmented film.

The exact changes occurring during the first few hours of test are not fully understood, but it is believed that a certain order of physical changes are shown by the complete potential-time curve. (Figure 6.) These changes are: 1) penetration of moisture, 2) passive film formation, 3) equilibrium or near equilibrium passive film formation and 4) loss of passivity with resultant corrosion.

Further consideration of these changes is given in the following explanation. If one considers a thin paint film through which moisture is diffusing, it appears possible for initial moisture reaching the metal interface to be low in concentration

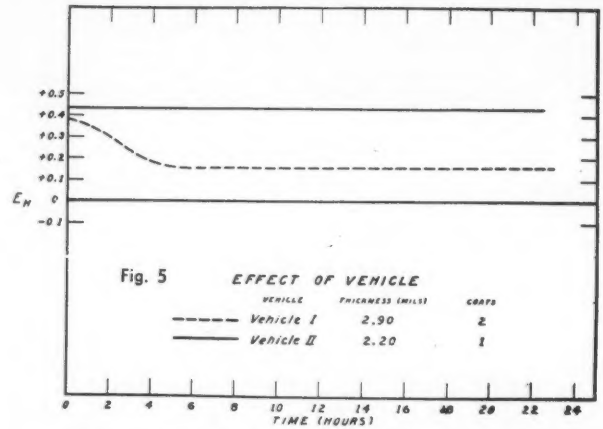



Fig. 5 EFFECT OF VEHICLE

| VEHICLE | THICKNESS (MILS) | COATS |
|---|---|---|
| Vehicle I | 2.90 | 2 |
| Vehicle II | 2.20 | 1 |

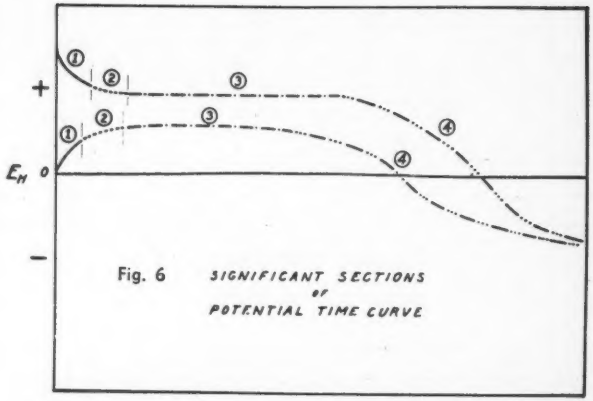



Fig. 6 SIGNIFICANT SECTIONS OF POTENTIAL TIME CURVE

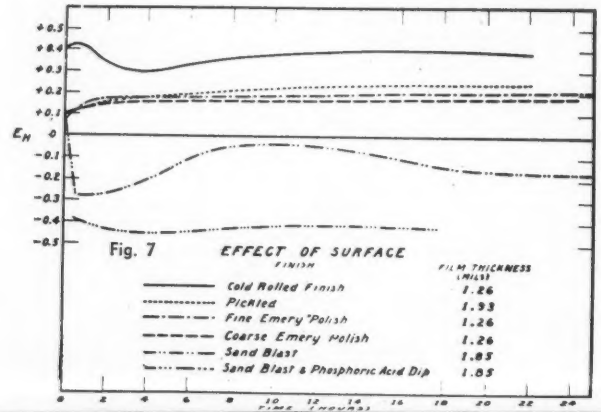



Fig. 7 EFFECT OF SURFACE FINISH

| FINISH | FILM THICKNESS (MILS) |
|---|---|
| Cold Rolled Finish | 1.26 |
| Pickled | 1.93 |
| Fine Emery Polish | 1.26 |
| Coarse Emery Polish | 1.26 |
| Sand Blast | 1.85 |
| Sand Blast & Phosphoric Acid Dip | 1.85 |

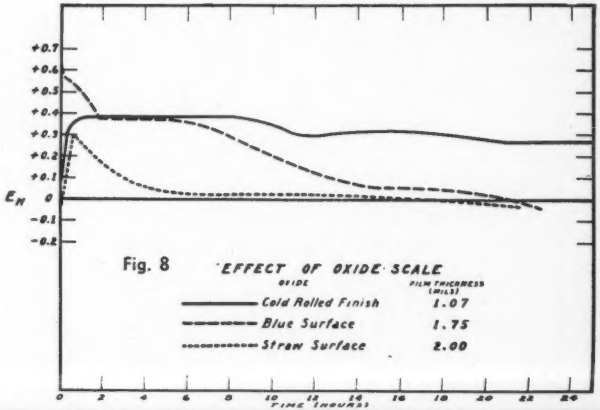



Fig. 8 EFFECT OF OXIDE SCALE

| OXIDE | FILM THICKNESS (MILS) |
|---|---|
| Cold Rolled Finish | 1.07 |
| Blue Surface | 1.75 |
| Straw Surface | 2.00 |

of inhibitive ions. With such thin permeable films it seems possible that rate of moisture diffusion through the vehicle envelope about each pigment particle, followed by dissolving of soluble constituents and rediffusion away from the particle towards the metal interface, will be slower than rate of moisture penetration directly to the metal interface. With time, the concentration of inhibitor ion may be expected to increase until diffusion into the main body of liquid above the paint film occurs, than when the concentration of inhibitor required for passivity may become too low and the potential drops.

### Effect of Surface Preparation

Field tests have shown how different surface preparations prior to painting can affect paint performance and this next series of results shows the effect of surface preparation on potential-time results. Again, it is not intended to evaluate the merits of one type of surface over another as a base for painting but only to show the response of the test to such variables.

The following surface conditions were studied: Cold-rolled finish, coarse and fine emery abraded surfaces, sulfuric acid pickle, sand blasted and sand blast plus phosphoric acid dip surfaces. All test material was originally of one lot of cold-rolled strip. This was used in the "as received" condition except for solvent cleaning or prepared for use as follows:

Emeried surface panels were prepared by hand polishing using No. 0 grit for fine surface and No. 1 grit for the coarse surface.

Sulfuric acid pickled panels were prepared by cleaning the cold-rolled strip in 15 percent sulfuric acid (inhibited for 15 minutes at 160° F.).

### Method of Preparing Panel Sets

Sand-blasted panels were prepared by use of sand (100 percent of which would pass a 13-mesh sieve and be retained on a 22-mesh sieve) at 50 pounds pressure. A second group of panels was prepared in the same manner except that the blasting operation was followed with a dip in 10 percent phosphoric acid at 160° F., and allowing the panels to air dry before paint application.

Pigment A in vehicle II paint was used in these tests and tap water was used as the contact solution.

From Figure 7, it is apparent that very slight difference is indicated by the use of two emeried surfaces and the pickled surface as a base for paint. There was, however, considerable variation between the cold-rolled finish and the sand-blasted surfaces. Considerable rust was found under the paint film applied to the sand-blasted test panels as well as numerous tiny bright metallic points.

### Metallic Peaks Result from Sand-Blasting Operations

Sand-blasting operations, while undoubtedly effective as a means of increasing paint adherence, may be detrimental because of greater surface activity developed. Further, metallic peaks resulting from the surface working causes considerable variation in film thickness over surface valleys and surface peaks. Reduced film thickness over the peaks would make them more susceptible to corrosion. The increase in potential after several hours indicates a

recovery effect of the paint in overcoming the surface effects of sand blasting.

That the phosphoric acid dip apparently aggravated the condition of sand blasting may be due to the incomplete phosphate films formed. Concentrated corrosion attack could result due to decreased anodic areas.

These results, which are reproducible, are believed to show the importance of considering surface preparations prior to test.

Something else to be considered in regard to surface conditions is the presence of surface oxide films. Again field tests have shown how important this variable can be regarding paint performance.

This series of tests was run to determine how various thicknesses of oxide layers affect results of potential-time studies.

Solvent-cleaned, cold-rolled strips were heated in a furnace. Two variations in time of heating were used, which resulted in the formation of a straw colored oxide layer in one instance and a dark blue oxide layer in the other. The cold-rolled finish material, cleaned as received, was used as being representative of a very thin uniform oxide layer. The blue oxide film was considered of a thickness comparable to that encountered on thin hot-rolled steel products. The light straw oxide was intended to represent an intermediate thickness of oxide film.

Pigment B in vehicle I was used in these tests and tap water used as contact solution.

It will be seen in Figure 8 that state of surface oxidation can greatly affect potential-time curves.

In considering the results obtained in these tests, it must be remembered that it is difficult to reproduce the exact same type of oxidation over the entire metal surface and to obtain any sure degree of oxide continuity when thick films become involved. A porosity test should be used to insure duplicate surfaces.

## Summary

Our investigations on the use of potential - time curve analysis of paint films have shown it to be sensitive to a number of factors other than those mentioned here. Space does not permit a detailed discussion of our studies on this technique but the following summarizes the important factors of the test, which make it a valuable, simple laboratory analytical tool:

1) With care, reproducible results are easily obtained.
2) The test is sensitive to factors known to influence paint field performance such as--
   a) vehicle used
   b) pigment used
   c) overall paint formulation
   d) method of surface preparation
   e) metal surface oxide condition
   f) chemical character of contact solution
   g) thickness of paint film

It is believed that potential-time studies can be made a valuable method for obtaining fundamental information as to what happens underneath metal protective paint films.

## References

[1] R. M. Burns and H. E. Haring, Trans. Electrochem. Soc., **69**, 169, 1936.

# Suburban Philadelphia Electrolysis Committee*

*By Paul Ganser*

**Gas Department, Philadelphia Electric Company, Philadelphia, Penna.**

THE FIRST and only Electrolysis Committee formed in suburban Philadelphia was started approximately 31 years ago. Known as the "Delaware County Electrolysis Committee," it functioned officially only within Delaware County and consisted of an Executive Committee and Sub-Committee. The former group was made up of utility executives, while the latter group consisted of engineers and test men responsible for all testing and for the reports of such tests. The Chairman of the Sub-Committee, appointed by, and a member of the Executive Committee, presented the reports prepared by his men to the executives for approval. For ten years the Delaware County Electrolysis Committee operated in this manner.

In 1927, the Delaware county association was reorganized without an Executive Committee, confining the work to the engineers and test men. This, however, did not prove entirely satisfactory, as there were no officers and there was no one to coordinate the work. So, in 1930, a chairman was elected, who supervised the work, conducted the meetings, kept the records and directed all correspondence.

For a number of years, the Delaware County Electrolysis Committee often found itself unofficially operating outside county boundaries. For this reason, it was decided, in 1943, to change the name to the "Suburban Philadelphia Electrolysis Committee," functioning throughout the counties of Delaware, Chester, Montgomery and Bucks.

The present committee consists of engineers and test men representing 14 companies. The personnel allowed to each concern is unlimited, except in the case of a vote. All records are retained by the chairman and are easily accessible on request. No reports are written, except on very special occasions, the minutes of the meeting generally cover sufficient data to be considered a record or report.

The conference room is donated by a member company; costs of stationery and supplies are overcome by contributions from members, office work, including stenographer, is donated by the chairman.

In the field, the conference room, is generally under a tree or in the chairman's car.

Each company furnishes its own testing equipment, except in cases where special equipment is required. In such cases, the companies having such equipment available are asked to supply the needs.

In 1943, a complete list of all the drainage connections, both forced and natural, was made by each company and filed with the chairman, who compiled these listings into one record, copies of which all members

* A paper presented at the North East Regional meeting of NACE in Philadelphia, Penna., Jan. 29, 1947.

received. The tabulation gave the exact location, the type of drainage and the current values of each connection.

If anyone desires to make any changes in the drainage connections, it is necessary to notify the chairman, who advises all members, and it is up to each one to change his original list accordingly. If a member feels these changes will in any way affect his or some other member's structures, he will notify the chairman, who will call a meeting of the committee.

For example, suppose a traction company desires to shut down a substation. First, the representative of that company notifies the chairman who, in turn, advises all members, and then calls a meeting of the committee. At the meeting, the problem will be discussed, plans made as to the type of test, the equipment needed, its availability, who will supply it, and the date, time and place of meeting for the start of the field tests.

Generally, a schematic is drawn, showing the locations of the various structures, key points of tests and drainage connections. Numbers are assigned to key test points and drainage connections by the chairman or someone designated by him. Numbering aids materially in identifying connections in calculating the data.

After assigning numbers to the drainage connections, large test currents are put into the connections in their corresponding turns and the effects of these currents are observed at other test points on all structures. Each company is required to make tests on its own structures. However, should one need assistance, it is always available and freely given by other members.

As soon as the network constants[1] and the mutual correlations between the structures are finished, they are immediately computed to see if any changes should be made before proceeding with the testing. The reason for this is, should the data indicate a contact between structures, or other unforeseen interference that must be removed before continuing with the testing, it can be done immediately without making useless tests.

By tabulating the computations of the data when taken, it is possible to easily change the plan of attack; and when the work is done, one can feel reasonably sure that it will not be necessary to go back for tests usually forgotten.

Working in this manner, with equipment and personnel immediately available, necessary tests can be made with ease, and not delayed several weeks, or even months, as has happened in the past. Therefore, at the completion of the field work, it is reasonable to assume that a final decision will be made at the next regular meeting, where a vote is taken of each individual member to the satisfaction of all companies.

From the outline of past and present methods of operation here presented, it may be readily seen that many changes have occurred, and a wealth of information obtained, which naturally leads to a more thorough understanding of the problem, and culminates in better cooperation and results.

[1] "Network Method"—Dr. Scott Ewing's book "Soil Corrosion and Pipe Line Protection"—Chapter X, page 216.

# A Study of the Corrosion of Copper Alloy Condenser Tubes*

*By N. W. Mitchell*

**Metallurgical Engineer, Chase Brass and Copper Company, Waterbury, Conn.**

THE importance of the corrosion of copper alloy condenser tubes[1] to the petroleum refiner and the mechanical engineer has encouraged a large amount of study, which has resulted in major improvements in alloy on the one hand, and treatments to modify the corrosive conditions on the other. The development of antimonial admiralty, for instance, greatly improved the average condenser tube life in the refinery, while at the same time the practice of desalting the crude oil rendered conditions less corrosive to tubes. A point was reached some time ago from which further progress both in metallurgy and in the treatment of plant conditions has been slow.

## Primary Causes of Corrosion

This paper presents some hitherto unpublished data derived from field corrosion tests, and summarizes the present state of our knowledge of the corrosion of copper alloy condenser tubes in refinery and gasoline plant service.

The principal causes of the corrosion of metal are listed as follows:

1. Electrochemical corrosion.
   - Evolution of hydrogen or replacement of metal.
   - Local cell action.
     - Difference in metal composition (galvanic action).
     - Differential aeration.
       - Water line (also due to other causes).
       - Deposit attack.
     - Differential movement.
     - Differential concentration.
     - Difference in temper.
     - Differential illumination.
2. Chemical corrosion.
   - Direct chemical reaction.
     - Sulphur.
     - Halogens.
     - Oxygen.
     - Certain organic chemicals.

Accelerating factors.

1. Stress corrosion.
2. Corrosion fatigue.
3. Velocity effects (impingement attack).

Galvanic corrosion involving copper alloys has been of very rare occurrence in refineries. Copper alloys are cathodic to most of the other commonly used metals and galvanic

★A paper presented at ASME meeting, Tulsa, Okla., Oct. 7-9, 1946.

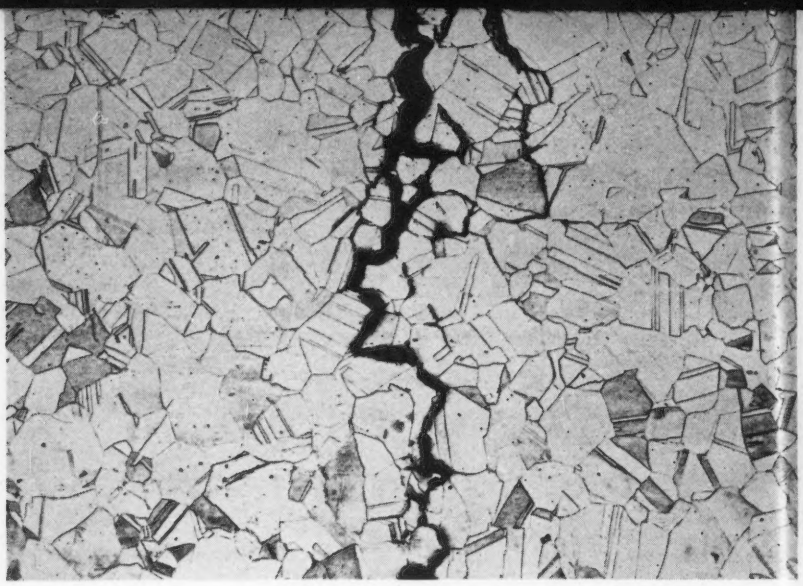


Figure 1—Stress-corrosion cracks in brass tube. Cracking is typically intercrystalline. Approx. × 100.

corrosion, if any, would usually be expected to occur at the expense of the non-copper alloy of a combination involving a copper alloy and some other base metal. In practice, this seems to have been confined to a few cases where steel tube sheets have corroded by pitting adjacent to the condenser tubes on the water side of the unit.

Some attempt has been made to protect condenser tubes by using an external electromotive force to maintain the tubes or the entire condenser cathodic to the rest of the equipment. Because most corrosion occurring in the refinery is not of the galvanic type and because the tubes are cathodic anyway, this practice has not been of notable benefit.

Stress-corrosion cracking has been a rather common source of failure of brass alloys. Stress corrosion may occur when the metal is in a stressed condition in a corrosive atmosphere. Since condenser tubes are furnished as annealed, there can be no residual stresses in the tube resulting from fabrication; hence stress-corrosion cracking in the refinery is usually, if not invariably, the result of operational stresses. In practice, the corrosive atmosphere contains ammonia or a substitution product, plus moisture and oxygen.

It has recently been reported that carbon dioxide may accelerate this action.[2] Mercury and mercury compounds are the most active in causing stress corrosion, but are not normally encountered in practice. Recently, however, several tubes cracked in less than 24 hours as a result of stress corrosion by mercury compounds, which were apparently accidentally introduced into the heat exchanger unit.

Typical stress-corrosion cracks are shown in Figure 1. They are usually but not always intercrystalline. The high zinc brasses are most susceptible to stress corrosion,

Figure 2—Radial longitudinal section of an admiralty tube (Cu 70.37, Sn 1.15, As 0.04, Fe 0.01, Zn [by diff.] 28.43) which has suffered intercrystalline corrosion. Approx. ×75.

whereas those of less than 15 percent zinc have high resistance. Stress-corrosion cracking of copper or of 30 percent cupronickel very rarely occurs.

Under some conditions, simple attack along the grain boundaries of the metal occurs in the absence of stress. This attack quite frequently penetrates the surface of the metal to a depth of several grains. It is not as common as stress-corrosion cracking and has been noted principally only in certain types of alloys. Figures 2 and 3 illustrate typical cases of intercrystalline corrosion found in oil refinery service.

Corrosion fatigue sometimes occurs in oil refinery heat exchanger or condenser tubes. This phenomenon is manifested by cracks originating at a surface roughened by corrosion. This roughening of the surface by corrosion concentrates any stresses in the metal and leads to failure by fatigue. Quite frequently fatigue cracks occur in connection with severe attack by sulphur or by chlorides plus sulphur.

Fatigue cracks, as shown in Figures 4 and 5, are usually transcrystalline as opposed to the intercrystalline stress-corrosion cracks. The cracks in this example originated in corrosion pits in the surface. They sometimes originate in areas which have suffered intercrystalline corrosion, as shown in Figure 6.

Impingement corrosion, or as it is sometimes called erosion-corrosion or inlet end corrosion, resulting usually from attack by high velocity cooling water or water containing entrained air or sand, is experienced in only three or four refineries in the United States. Cupronickel and aluminum brass are the alloys best adapted to resist this corrosion, and are recommended if their use can be tolerated, based on conditions on the shell side of the tube. Frequently conditions causing this attack may

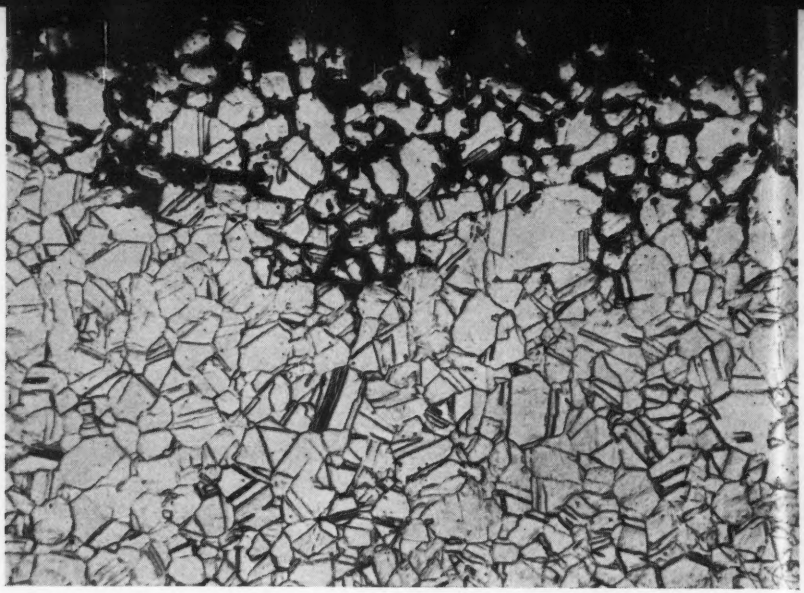


Figure 3—Part of section of Figure 2. Approx. × 250.

be corrected by relocation of the water intake, reduction of velocity, or removal of air or sand from the water.

Results of corrosion as they are visible on the metal are listed as follows:

1. Uniform or general thinning.
2. Pitting.
   - Shallow.
   - Deep.
   - Elongated.
3. Selective solution.
   - Removal of one constituent of an alloy (dezincification).
   - Local.
   - Uniform.
4. Intercrystalline corrosion.

In the oil industry, sulphur corrosion results in direct formation of copper sulphide on the surface of the metal, which is usually thinned rather uniformly or attacked by shallow pitting beneath the heavy black layer of sulphide. The high copper alloys are rapidly attacked by sulphur, but the rate of attack diminishes markedly as the copper content decreases. Alloys containing 85 percent or more copper are practically unusable where sulphur attack occurs. Figure 7 shows the appearance of a tube which has suffered attack by sulphur compounds.

Dezincification is a phenomenon which formerly was the cause of

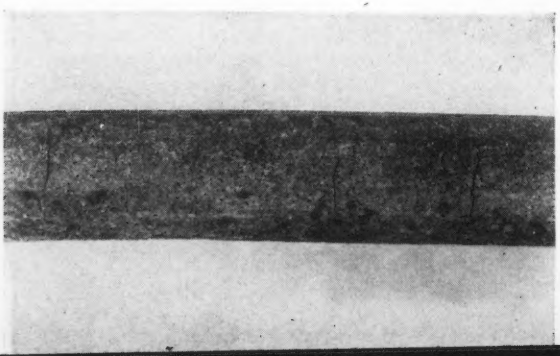


Figure 4—Transverse corrosion-fatigue cracks in admiralty tube used in oil refinery. Approx. × 1.

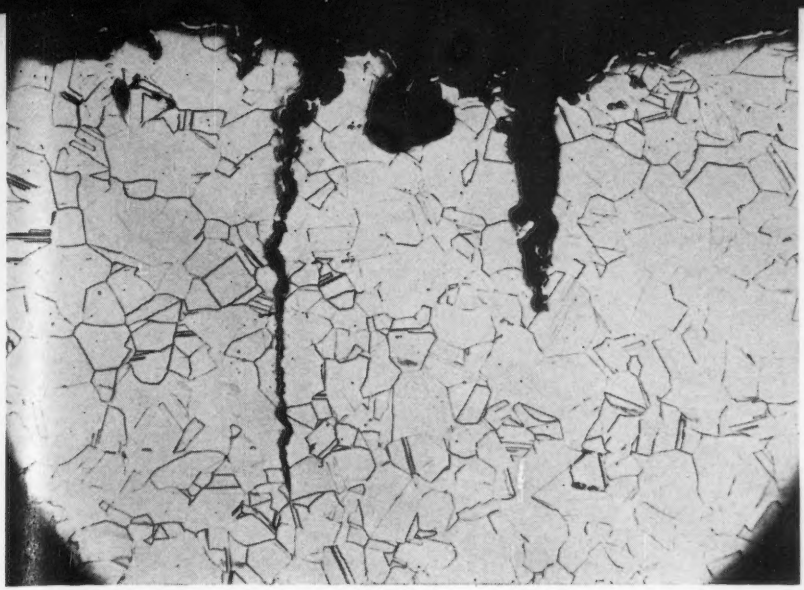


Figure 5—Radial longitudinal section of tube of Figure 4 showing corrosion-fatigue cracks. Approx. × 250.

about half of the admiralty tube failures in refinery and gasoline plants. The addition of antimony was discovered to prevent, or at least greatly reduce dezincification, and its use as a condenser tube alloy has greatly improved the life given by condenser and heat exchanger tubes.

Figure 8 shows the effect of adding antimony to some high brass alloys. The marked effect of antimony in preventing dezincification, and at the same time reducing the overall corrosion of the metal is evident.

Figure 9 is a photomicrograph of an admiralty tube which suffered local dezincification, and Figure 10 is a comparison of plain admiralty with antimonial admiralty by two tubes which were in service the same length of time in the same unit.

In designing a corrosion test, either for the laboratory or for field testing, the various causes of corrosion must be considered together with the results visible on the metal. Corrosion testing is carried out for the purpose of determining the corrosion resistance of a metal or alloy, to learn whether it may be economically used under certain given conditions. Such knowledge can, of course, be obtained by using the alloys under consideration in service, but this usually takes too long a period of time. Laboratory testing is therefore used to obtain approximate results in a relatively short period.

Laboratory testing, however, even under the best conditions, cannot be expected to simulate exactly conditions in the refinery. For several years we have been very successful in conducting corrosion tests in the refinery under conditions closely approaching those of actual service. The tests are carried out using thin strip tensile test specimens, arranged on racks as shown in Figure 11. A detailed description of laboratory

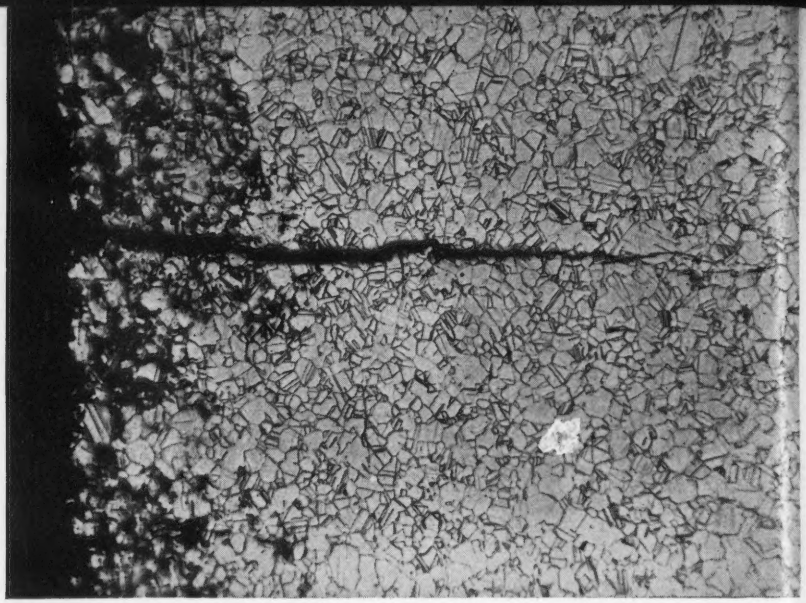


Figure 6—Corrosion-fatigue cracks in admiralty tube (Cu 70.90, Sn 1.00, As 0.05, Zn [by diff.] 28.05) emanating from surface which has experienced intercrystalline corrosion. Approx. × 150.

corrosion testing using such specimens was given by Crampton and Mitchell in ASTM Symposium on Corrosion Testing Procedures, 74-86 (1937), and the field corrosion testing was described by the same authors in Oil and Gas Journal, Vol. 36 (30) 69-71 (1937).

In Table 1 are listed a number of cases taken from the study of corrosion tests in the field where the attack was predominately by sulphur and sulphur compounds. It will be noticed that the alloys of admiralty are much superior to the other alloys tested under conditions of sulphur attack. This would be expected as it has been quite definitely determined that the lower the copper content of the alloy, the better its resistance to sulphur.

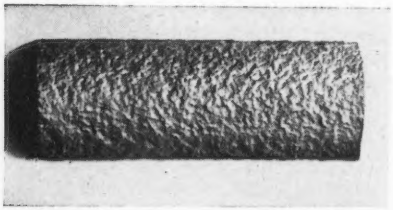


Figure 7—Typical appearance of surface of admiralty tube which was attacked by sulphur in oil refinery service. Approx. × 1.

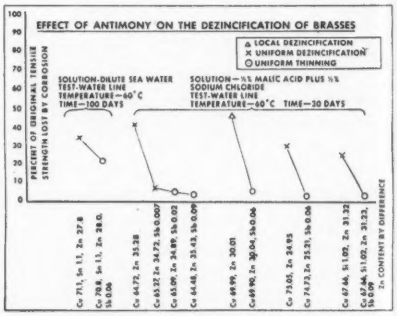



Figure 8—Effect of adding antimony to some high brass alloys.

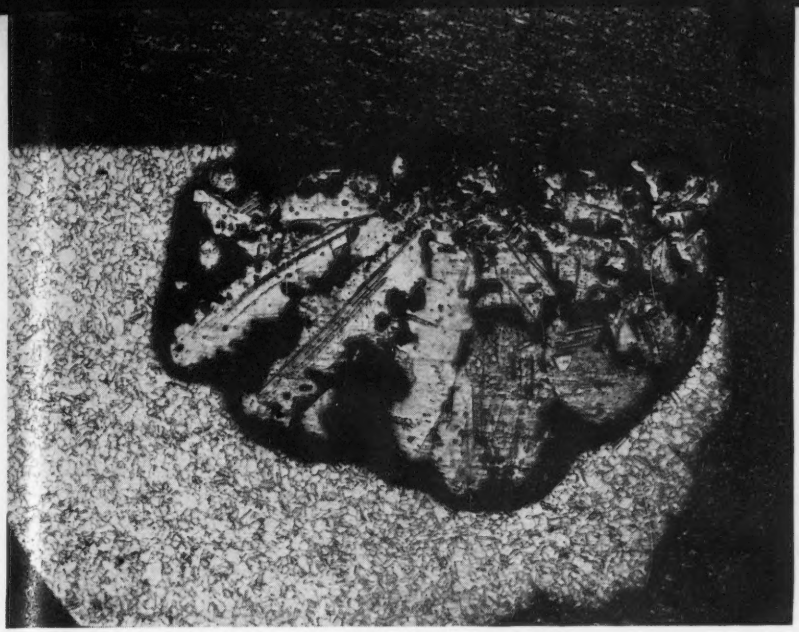


Figure 9—Plain admiralty tube with dezincified plug in surface. Approx. × 75.

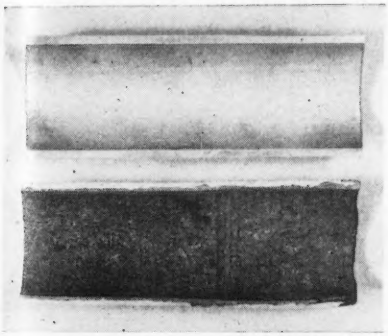


Figure 10—Sections of admiralty condenser tubes after two years simultaneous service in same refinery unit. Upper: plain admiralty tube (Cu 70.68, Sn 1.02, Fe 0.01, Zn [by diff.] 28.29) is badly dezincified with the wall 0.065 inch completely penetrated. Lower: antimonial admiralty tube (Cu 70.71, Sn 0.90, Sb 0.05, Fe 0.001, Zn [by diff.] 28.33) is in excellent condition and shows only uniform thinning from 0.065 inch to 0.056 inch. It has not suffered dezincification. Approx. × 1.

In this connection, Muntz metal, which has even a lower copper content than admiralty, exhibits excellent resistance to sulphur. However, its known susceptibility to dezincification as well as stress-corrosion cracking, excludes it for practical use.

The antimonial admiralty and admiralty without antimony behave

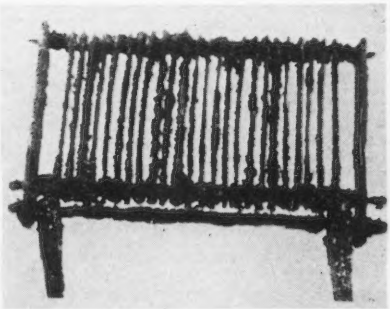


Figure 11—Rack of corrosion specimens after test in heat exchanger. Approx. × 1/5.

**TABLE 1**

**Attack Predominantly by Sulphur.**

| Values are Percent of Original Tensile Strength Lost Due to Corrosion | Antimonial Admiralty 72 Cu, 1 Sn, 0.05 Sb, 26.95 Zn | Admiralty 71 Cu, 1 Sn, 28 Zn | Red Brass, 85 Cu, 15 Zn | 20% Cupro-nickel 80 Cu, 20 Ni | 30% Cupro-nickel 70 Cu, 2 Al 30 Ni | Alu-minum Brass 76 Cu, 2 Al 22 Zn | Muntz Metal 60 Cu, 40 Zn |
|---|---|---|---|---|---|---|---|
| 4 Months in Vapor Line, Top of Vacuum Tower | 2 | 2 | 63 | 66 | .. | .. | .. |
| 4 Months in Vapor to Oil Exchanger | 19 | 17 | 27 | 29 | .. | .. | .. |
| 4 Months in Gasoline Vapor Line | 7 | 8 | 23 | 27 | .. | 20 | .. |
| 3 Months in Vapor Stream at Top of Bubble Tower | 62 | 77 | 88 | 52 | .. | 100 | 79 |
| 5 Months in Vapor Side, Crude Still Partial Condenser | 9 | 6 | 7 | 7 | .. | 7 | .. |
| 5 Months in Oil Vapor Stream Leading to Condenser | 38 | 31 | 79 | 33 | .. | 43 | .. |
| 1 Month in Bubble Tower Vapors 386° F. | 4 | 4 | 16 | .. | .. | .. | .. |
| 4 Months in Stabilizer Reboiler Vapors 386° F. | 4 | 4 | 60 | .. | .. | .. | .. |
| 4 Months in Stabilizer Overhead Vapors 180° F. | 5 | 5 | 5 | .. | .. | .. | .. |
| 3 Months in Gasoline Vapor Line to Condenser | 8 | 6 | 10 | 8 | .. | .. | .. |
| 8 Months in Vapor Side, Unit Condensing Gasoline | 3 | 4 | 5 | .. | 8 | 4 | .. |
| 11 Months in Unit Condensing Heavy Gasoline Vapors | 9 | 10 | 14 | .. | 15 | 10 | .. |
| 19 Months in Vapor Side of Flash Tower Overhead Condenser | 4 | 3 | 3 | .. | 2 | 3 | .. |
| 6 Months in Condenser Shell, Water and Gasoline Condensed | 13 | 14 | 23 | 10 | .. | 13 | .. |
| 6 Months Submerged in Water-Gasoline Condensate | 8 | 8 | 10 | 4 | .. | 6 | .. |
| 5 Months in Caustic Side of Stream to Caustic Exchanger | 39 | .. | 100 | 15 | .. | .. | .. |
| 3 Months in Treated Gasoline Vapors at 300° F. | 48 | 55 | 44 | 27 | .. | 63 | .. |
| 9 Months in Experimental Condenser, gasoline Vapor | 16 | 12 | 22 | 7 | .. | 10 | .. |
| 8 Months in Reflux Condenser | 6 | 11 | 10 | 10 | 11 | .. | .. |
| 5 Months in Vapor Line to Condenser | 15 | 25 | 39 | 13 | .. | 44 | 44 |
| 3 Months in High Stage Condenser—Bottom Center | 17 | 22 | 49 | .. | 23 | .. | .. |
| 3 Months in High Stage Condenser—Top Center | 20 | 17 | 22 | .. | 30 | .. | .. |
| High Pressure Fractionating Column of Dubbs Unit: | | | | | | | |
| 1.4% Sulphur, 121 Days at 698° F. | .. | .. | 100 | .. | .. | .. | 53 |
| 1.4% Sulphur, 115 Days at 680° F. | 16 | 13 | 100 | .. | .. | .. | 12 |
| 1.4% Sulphur, 26 Days at 599° F. | 6 | 7 | 100 | .. | 100 | 7 | 7 |
| 1.4% Sulphur, 27 Days at 545° F. | 4 | 2 | 100 | .. | 100 | 16 | 1 |
| 1.4% Sulphur, 27 Days at 491° F. | 2 | 2 | 100 | .. | 57 | 10 | 1 |

**TABLE 2**

**Attack Predominantly by Water and Special Cases.**

| Values are Percent of Original Tensile Strength Lost Due to Corrosion | Antimonial Admiralty 72 Cu, 1 Sn, 0.05 Sb, 26.95 Zn | Ad-miralty 71 Cu, 1 Sn, 28 Zn | Red Brass, 85 cu, 15 Zn | 20% Cupro-nickel 80 Cu, 20 Ni | 30% Cupro-nickel 70 Cu, 2 Al 30 Ni | Alu-minum Brass 76 Cu, 2 Al 22 Zn | Muntz Metal 60 Cu, 40 Zn | Copper |
|---|---|---|---|---|---|---|---|---|
| 38 Days in Contact with Vapors from Alum Evaporator | 47 | 96 | 44 | 44 | .. | .. | .. | .. |
| 15 Months in Corrosive Water | 2 | 0 | 1 | 0 | .. | 3 | .. | .. |
| 5 Months in Cooling Water to Condenser | 8 | 5 | 5 | 4 | .. | 4 | .. | .. |
| 4 Months in Condenser-Box Water 125° F. | 2 | 1 | 0 | .. | .. | .. | .. | .. |
| 3 Months in Cooling Water to Condenser | 5 | 3 | 2 | 3 | .. | .. | .. | .. |
| 5 Months in Condenser-Box Water | 4 | 12 | 3 | 0 | .. | 2 | 34 | .. |
| 12 Months on Water Side of Flash Tower Overhead Condenser | 33 | 50 | 51 | .. | 39 | 53 | .. | .. |
| Special Case. Benzol, Chlorinated Hydrocarbon, Steam at 160° F. | 36 | 45 | 48 | 14 | .. | .. | .. | 48 |
| Special Case. Specimens Immersed in Carbon Black Paste 20 Days | 2 | .. | 2 | .. | 2 | .. | .. | 9 |

approximately the same in most of the tests shown in this table. Here again the dependence of sulphur corrosion on copper content is shown. The cases definitely show that cupronickel is not satisfactory for handling sulphur compounds, a fact which restricts its use in the oil industry. Thirty percent cupronickel is, however, very satisfactory in a number of locations where severe attack by acid occurs, and where temperatures are high.

Table 2 shows several cases in which water corrosion was the principal factor, and also lists two cases of especial interest. In these water corrosion cases, as would be expected, antimonial admiralty shows marked superiority over admiralty without antimony. In some cases, the antimonial admiralty is better than red brass.

It is believed that the type of field corrosion testing here described, combined with observation of the behavior of condenser tubes in service will continue to yield beneficial results. Corrosion knowledge is essentially empirical, and the more test data we have, the better able we shall be to handle the new corrosion problems expected to attend the growth of the petroleum chemical industry.

## References

1. H. L. Burghoff, Corrosion of Copper Alloys, ASM, Corrosion of Metals Symposium, Cleveland, Ohio, 1946. Figures 1-6 are from this article.
2. Joint ASTM and AIMME, Symposium on Stress Corrosion Cracking, Philadelphia, Penna., 1944.

# Mechanical and Metallurgical Control of Sulphuric Acid Corrosion in Petroleum Processes★

*By E. R. Wilkinson*

Standard Oil Company of New Jersey, Baton Rouge, Louisiana

A MODERN complete oil refinery cannot operate successfully without the use of large quantities of sulphuric acid. Many of the processes require the use of sulphuric acid to such an extent that some large refineries use several hundred tons each day. Corrosion from this acid is as common to the refiner as any corrosion problem with which he is confronted, and it has been one of his major problems ever since the very inception of oil refining.

Early processes which used sulphuric acid from the start still depend on it and newly developed processes employ it with the full realization that corrosion is to be expected. The corrosion in some of the newer processes has been found to be just as severe, if not more so than that which has been experienced for years in some of the old treating processes.

In years past, there has been too much tendency to just accept this corrosion as an inherent part of the operation and to simply replace worn out equipment in kind after it reached the end of its short useful life. Since the corrosion problem exists, it must be recognized, but with determination to continually search for better means of controlling it.

The important part that this corrosive material plays in the manufacture of petroleum products certainly warrants giving this problem at lot of attention.

It is not the intent of this paper to imply or predict any astonishing innovations that might lead to the belief that corrosion from sulphuric acid can be readily or entirely eliminated. The purposes are simply to review briefly the basic factors which exert some influence on the degree of sulphuric acid corrosion, present a few interesting experiences, and then discuss some of the mechanical and metallurgical means at our command for effecting systematic control even though it may not completely eliminate the corrosion in all cases. A further purpose too is to stimulate more interest in this particular subject among refinery engineers and manufacturers of

★A paper presented before the Petroleum Committee at the ASME meeting in Tulsa, Okla., Oct. 7-9, 1946.

corrosion resistant materials so that an increasing amount of enthusiastic attention might be devoted to it.

### Factors Influencing Corrosion

There are many factors which may influence the corrosion of materials by sulphuric acid. Some of them are doubtless unknown to us and others we know little about, but there are certain principal or basic factors which we know exist and have a direct bearing on corrosion rates. These are: 1) acid strength or concentration, 2) acid temperature, 3) oxygen content of fluid, 4) velocities and turbulence, and 5) electrolytic action. These must be considered both individually and collectively in various combinations for every case, since the extent of the corrosion is by no means a direct function of the number of these factors which may be present.

In some observations certain combinations have actually shown a beneficial effect on certain materials and at the same time have shown a decidedly detrimental effect on other materials. It is, therefore, most important that none of these factors be neglected in any study of a sulphuric acid corrosion problem. In briefly reviewing them, no particular significance need be attached to the order in which they are discussed, since this order has not been predetermined and since it is difficult to say that any one is more important than another.

### Acid Strength or Concentration

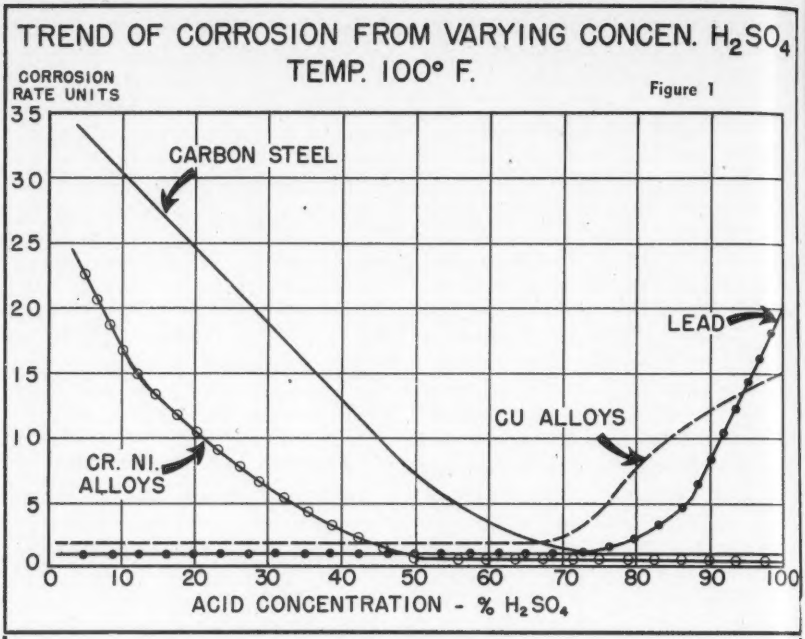
The strength or hydrogen ion concentration of the acid is a factor which comes to mind almost without thought. The influence of the acid strength is in itself well known and fairly straightforward, but still certain questions regarding acid strength are highly debatable. For instance, ordinary carbon steel material does not corrode in concentrated sulphuric acid, if all other factors are assumed to be ideal. However, many people will argue strenuously over that point of concentration at which steel begins to corrode at a rate which makes it cease to be economical. In some circles of thought, the figure may be 65 weight percent and in others 75 percent, and it will likely vary anywhere between 60 and 80 percent.

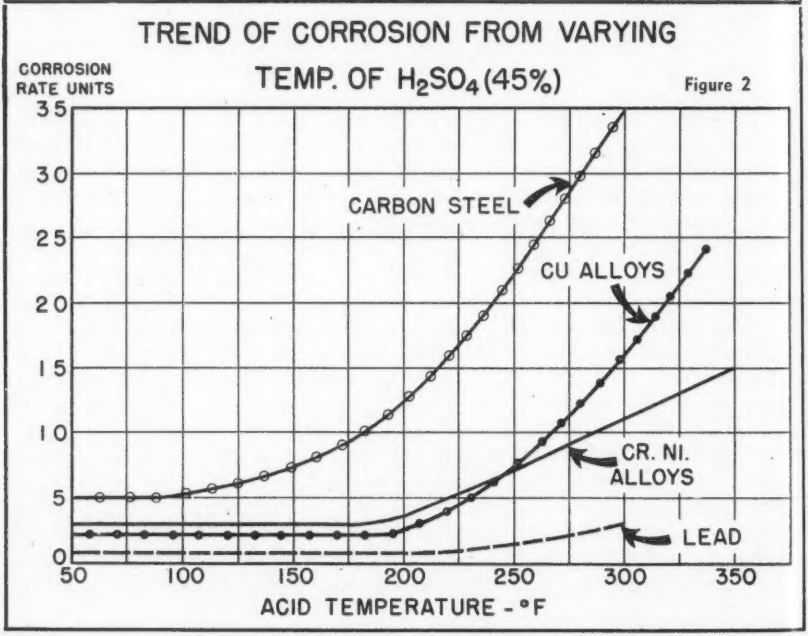
### Reaction Not Always Same

Experience has actually shown some cases where acid of 50-60 percent concentration was not as corrosive to steel as 70-80 percent acid, all of the basic factors being essentially comparable. In such cases, it could only be concluded that the lower strength solution contained some inhibitor that the higher strength solution lacked. In this connection, it has been demonstrated on several occasions that black acid containing carbon from an operating unit is less corrosive than white acid for the same concentration range. This simply means that for strength alone to be the controlling factor all other conditions must be ideal, or at least they must be controlled.

The curves in Figure 1 show in general the relative effect or general trend of corrosion on some of the more common materials by variations in concentration. These curves assume essentially no effect from other factors and are based on general knowledge from plant operating and laboratory data.

It is generally agreed that sul-


TREND OF CORROSION FROM VARYING CONCEN. $H_2SO_4$
TEMP. 100° F.
Figure 1
CORROSION RATE UNITS
35
30
25
20
15
10
5
0
CARBON STEEL
LEAD
CU ALLOYS
CR. NI. ALLOYS
0 10 20 30 40 50 60 70 80 90 100
ACID CONCENTRATION - % $H_2SO_4$


TREND OF CORROSION FROM VARYING
TEMP. OF $H_2SO_4$ (45%)
Figure 2
CORROSION RATE UNITS
35
30
25
20
15
10
5
0
CARBON STEEL
CU ALLOYS
CR. NI. ALLOYS
LEAD
50 100 150 200 250 300 350
ACID TEMPERATURE - °F

phuric acid becomes increasingly more corrosive as its temperature is increased. This, however, is not universally true, because if the acid contains oxygen, it may actually become less corrosive to some alloys as temperature is increased to the point of driving oxygen from the acid. This applies to nearly all copper bearing alloys, which are corroded more rapidly by sulphuric acid containing dissolved oxygen than by sulphuric acid which is oxygen free. It must be remembered, however, that if the temperature is increased appreciably beyond the point required to expel oxygen, then the corrosion rate will, in all probability, again increase. When considering temperature in making the selection of materials, distinction should be made between fluid and metal, or skin temperatures. For instances, in some acid heaters, the fluid or solution temperature may be only 275 or 300° F., but the skin or metal temperature of the heating elements may be as much as 100 to 200° F. higher. And this higher temperature is the one which has the most effect on possible corrosion of the heating elements. Corrosion-wise, the more common brasses and chrome nickel alloys have not been satisfactory for temperatures above 275° F. For temperatures in excess of 275° F., reliance must be placed in special alloys, or inert materials such as carbon.

### General Trend of Corrosion on More Common Materials

The curves in Figure 2 show the general trend of corrosion on some of the more common materials by 45 percent acid when temperatures are varied. As in the case of Figure 1, these curves are based on general plant operating and plant data, and they should not be considered to show exact performance of a material under specific conditions. Further, there is no direct relationship between the Corrosion Rate Units in Figures 1 and 2.

### Oxygen Content of Fluid

Oxygen in sulphuric acid may increase its corrosive action on some metals, although it may actually decrease the corrosion rates on other metals. Laboratory tests, for instance, have shown that the corrosion rate may be increased as much as 10 to 20 times on carbon steel if the acid solution is saturated with oxygen. Even being saturated with air will greatly increase the corrosion rates on steel. This same phenomenon is true of copper and nickel, and their alloys to a large extent. However, oxidizing agents that accelerate corrosion of these materials will usually reduce the corrosion of alloys containing a metal such as chromium. For instance, experience as well as laboratory tests have shown that chrome-nickel alloys will, in some cases, resist the corrosive action of weak sulphuric acid containing air, whereas the copper alloys are rapidly corroded under the same conditions. Conversely, the copper alloys are highly resistant to weak acid which is air free, whereas the chrome-nickel alloy may be rapidly corroded. The reason for this peculiarity is that protective oxide films are formed with such metals as chromium, which films are often much more corrosion resistant than the metal itself, whereas this is not true with such materials as copper and nickel.

**SUMMARY OF OPERATING EXPERIENCES**
**INDICATING SUITABILITY OF DIFFERENT MATERIALS FOR SPECIFIC APPLICATIONS**

| OPERATING PROCESS | TREATING | ALKY-LATION | ACID RECLAIMING, SEPARATING, & CONCENTRATING | | | | |
|---|---|---|---|---|---|---|---|
| ACID CONCENTRATION | 2-10% | 88-98% | 40-60% | 40-60% | 75% | 90% | |
| ACID TEMPERATURE | 100°F | 35°F | 200°-240°F | 240°-275°F | 275°F | 150°F | 300°-325°F |
| PIPE & VALVES | | | | | | | |
| CARBON STEEL | BAD | VERY GOOD AT LOW VELOCITY | — | — | — | VERY GOOD AT LOW VELOCITY | — |
| LEAD | VERY GOOD | — | VERY GOOD | GOOD | — | — | — |
| CORROSIRON OR DURIRON | — | — | VERY GOOD | VERY GOOD | VERY GOOD | — | VERY GOOD |
| HASTELLOY D | — | — | GOOD | GOOD | VERY GOOD | — | VERY GOOD |
| MONEL | GOOD (1) | BAD | GOOD | VERY POOR | — | — | — |
| EVERDUR | GOOD (1) | — | FAIR | POOR | — | — | — |
| RED BRASS | GOOD (1) | — | FAIR | POOR | — | — | — |
| YELLOW BRASS | FAIR (1) | — | FAIR | POOR | — | — | — |
| 18-8 CHROME-NICKEL | FAIR (2) | VERY GOOD | — | — | — | VERY GOOD | — |
| 18-8 CHROME-NICKEL MOLY. | GOOD (2) | — | — | — | — | — | — |
| WORTHITE | — | — | FAIR | POOR | VERY POOR | — | — |
| ALOYCO 20 | — | — | GOOD | FAIR | FAIR | — | — |
| LININGS | | | | | | | |
| LEAD | VERY GOOD | — | VERY GOOD | GOOD | — | POOR | — |
| ACID BRICK | — | — | — | GOOD | GOOD | — | GOOD |

*- Indicates no experience (1) If not aerated (2) If aerated*

Figure 3

This factor has been demonstrated on many occasions so that extreme care is necessary in determining as nearly as possible the oxygen content or possible air content of the solution before selecting the material for the equipment which is to handle the acid.

### Velocities and Turbulence

In discussing the effects of acid concentration, it was stated that concentrated acid would not appreciably corrode plain carbon steel material if all other conditions were ideal. This is due principally to the fact that actually a slight amount of corrosion does occur in the initial stages of operation, but from the products of this corrosion, a corrosion-resistant film is rapidly formed which actually protects the metal from further corrosion. If, on the other hand, high velocities accompanied by excessive turbulence are present, the corrosion products which form protective films may be carried away before the film is formed, or the film itself may be washed away if the velocities are variable such that under some operating conditions at low velocities a film might be formed.

Unfortunately, there does not seem to be any good practical method of applying laboratory data determinations of these critical velocities to actual field or plant installations. It has been difficult, too, to establish a maximum safe velocity in an operating unit because of the many variables which are encountered.

At least one experience is known wherein velocities in the order of 1.75 feet per second are slightly high for carbon steel to be economical. In most cases, however, it has been shown that if the velocity or turbulence is too high for carbon steel, then it generally follows that the chrome-nickel steels will offer enough advantage to make them more economical. Thus, little can be said about this factor until actual plant data have been collected and correlated, and, therefore, it is important to obtain accurate periodic data of this nature at such points in an operating system where real velocities or turbulence may exist.

### Electrolytic Action

Basically, one might argue that all corrosion is accompanied by electrolysis, if considered from the fundamentals of electrochemical theory. It is not intended that this question be debated herein but rather that a brief discussion be presented to indicate how the electrolysis occurs and show that caution is required in the selection of different materials for installation in the same system.

If conditions are such that the concentration of metallic ions in a solution at one point on a metallic surface is appreciably different from the concentration at another point, there will be a resultant difference in electrical potential which will cause a current to flow between the two points. Under such conditions, the metallic ions and corrosion products might be removed continuously at one point and deposited at another point. Thus, if dissimilar metals are used in contact with one another or even if they are separated but in close proximity of one another, a current flow between them may actually be established and this flow will be dependent on the relative positions of the metals in the

electromotive series. In such cases, the more noble metal or that one which is higher in the electromotive series will actually cause displacement of the other metal which is lower in the series. Thus, care must be taken in the design of any system for handling sulphuric acid, to assure that if dissimilar metals are used, they should not be in close proximity of one another or, if possible, there should not be a wide spread in the electromotive series between the dissimilar metals.

### Plant Operating Experiences

Sulphuric acid corrosion in acid treating and sulphuric acid alkylation units is of general interest to the refiner, but the biggest problems seem to be encountered in the auxiliary equipment that is necessary for acid reclaiming, separation, and concentration so that the acid can be reused. In all these operations, the latter three in particular, the most advanced mechanical and metallurgical methods of control must be applied if we expect the corrosion problems to be held in check sufficiently to permit economical justification for the use of sulphuric acid.

### Acid Treating

The acid treating of refined and lubricating oils is a process that is about as old as petroleum refining itself, and still we have problems from sulphuric acid corrosion. Treaters in many cases must be lined with corrosion-resistant materials, and the acid withdrawal lines and transfer pumps often have to contain corrosion-resistant alloys.

In these operations, the concentration of acid employed is usually high insofar as the initial injection of acid is concerned. However, the amount of acid passing through the system is only a relatively small percentage of the total volume of fluids and as it disperses very rapidly, little concentrated acid, as such, comes in contact with the equipment. Then, too, the acid itself, having a high degree of affinity for water, combines readily with any water in the system and the result is that the acid strength is reduced to very dilute proportions which makes it extremely corrosive even at atmospheric temperature conditions.

For this service, then the determination is one for a material which will give long service in contact with dilute 2-10 percent sulphuric acid solutions in oils (which in some cases are corrosive themselves) at essentially atmospheric temperature. Factors other than temperature and concentration are velocities and aeration principally. These, of course, must be taken into account if present in any appreciable magnitude.

### Lead, Copper-Bearing Alloys Suitable

Referring to curves in Figure 1, it is noted that either lead, or the copper-bearing alloys should be quite suitable in this service. The copper-bearing alloys, of course, may not be satisfactory if much air or oxygen is present in the system. Lead, although very good for corrosion resistance, always offers the mechanical problem of attachment to steel. Experience leads more and more to the belief that the installation of loose lead linings in vessels where linings are held in place by steel straps, which in turn are lead covered, should be kept to a mini-

mum. While this type of installation can be used, its first cost is high, and its maintenance cost is often exorbitant. Furthermore, it cannot be used satisfactorily in a pressure treater wherein it may be subjected to appreciable fluctuations in pressure. Thus, lead, which is thoroughly and completely bonded to the steel, is much more satisfactory and should always be given first consideration. Copper alloys such as Muntz metal, Everdur and Monel, have given good results in this service. Of course, if aeration is a factor, then these alloys may not be satisfactory, in which case a stainless steel of the 18-8 chrome-nickel type would probably be used if some piece of equipment were involved that would not permit the use of lead. Such alloys must be special, containing copper, molybdenum, or silicon, or combinations of these.

Reinforced gunite or cement linings have been used with some success in vessels that are in continuous treater service under 50 psi pressure. Penchlor acid cement has also been installed with steel reinforcing and has given very good service. The best type of reinforcement is a hexsteel or subway grating type, spot welded to the vessel on relatively close centers. Where horizontal drums are used, they can ordinarily be protected adequately by installation of such a liner only in the bottom half. Acid brick linings can be used but are not recommended because of excessive maintenance.

## Alkylation

In the sulphuric acid alkylation process, which is a comparatively new one compared to the one just discussed, the difficulty has resulted from handling concentrated (88-98 percent) sulphuric acid. The acid is about 98 percent as it enters the system, and the nature of the process is such that it remains in fairly concentrated form, being diluted mostly by carbon to about 88 percent. There is almost no chance for dilution of the acid to low, corrosive concentrations because the acid containing hydrocarbon streams are necessarily kept dry for proper operations, and to prevent icing at the operating temperatures which are close to the freezing point of water. With this low temperature, it can be recognized readily that the corrosion is not a function of temperature.

The acid hydrocarbon emulsion streams containing the concentrated acid are not normally corrosive to carbon steel, there is no problem of aeration of the acid, and apparently no electrolytic action. After some experience, it was learned that no corrosion existed in the system except at points of very abrupt changes in direction of piping, indicating a turbulent condition, and where the stream was moving at exceedingly high velocity. This latter condition, accompanied by extreme turbulence, is experienced in pumping equipment. In some locations, carbon steel is good for only a few weeks, and in others only a few months.

The best solution to this problem from a mechanical and metallurgical standpoint seems to be the use of stainless steel of the 18-8 chrome-nickel variety. A molybdenum containing 18-8 chrome nickel is superior to the straight 18-8. Experience will usually show that this material has a sufficiently long life as com-

pared to carbon steel, and its use can be economically justified.

### Acid Reclaiming

In acid reclaiming systems, various mixtures of acids and oils are encountered under a variety of operating conditions. The systems referred to here incorporate storage facilities and transfer lines and pumps from operating units to separating facilties and thence to acid concentrating units. From the operating unit to the separators, relatively concentrated acid at low temperature is usually involved and, beyond the separators, the acid is much weaker and at temperature conditions that make it extremely corrosive.

Except for the velocity and turbulence problem in transfer pumps and piping, carbon steel is generally satisfactory until the acid reaches the separating unit. After separation, the acid may be diluted to any concentration between 40 and 60 weight percent depending upon the separation that is desired and the carbon content of the acid being reclaimed. Temperatures in this portion of the system are likely to vary between 200° F. and 240° F. In addition, some oxygen may be present in the acid stream. Under these conditions, lead has been used quite successfully except for its mechanical strength deficiency. Hastelloy D, Corrosiron or Duriron, Worthite, Aloyco 20, and some of the copper-bearing alloys such as Monel, Everdur, Red Brass and Yellow Brass have been used in castings for pumps and valves with varying degrees of success.

Hastelloy D and Corrosiron or Duriron are very satisfactory from a corrosion standpoint. At the lower range of concentrations and temperatures, the copper bearing alloys prove fairly economical except that Everdur castings have presented a problem because of their porosity. In the higher concentrations and higher temperatures, the chrome-nickel alloys can be expected to give better service than the copper-bearing alloys.

### Acid Separating

Conditions within the separators themselves and their attendant pumps and piping are quite similar to those just discussed, except somewhat higher temperatures are involved. The concentration of the acid feed to the separators is usually in the order of 80-90 weight percent. This is immediately diluted in the separators and may vary within the vessels from 40 to 60 percent. Temperatures from about 240° F. to 275° F. are encountered.

### Certain Alloys Deemed Unsatisfactory Because of Design

The same general statements regarding suitability of materials in this operation may be made as were mentioned above in connection with reclaiming systems. However, there are two particular observations that deserve mention. Hastelloy D valves, although suitable from a corrosion standpoint, are very poor from an operational standpoint because of their mechanical design features. They have been found quite unsatisfactory in piping systems where coke is encountered. Copper-bearing alloys are very poor in acid concentrations of approximately 60 percent, with tempera-

tures of approximately 275° F. This is particularly true in the case of Monel. This was determined from a particular installation of a Monel pipe spool which operated without significant corrosion for some length of time until one batch of acid was separated at 60 percent and 275° F. During a very short period of operation, only a few days, this pipe spool lost almost half its weight.

### Acid Concentrating

In acid concentrating units, where acid is concentrated from the 40-60 percent range leaving the separators, up to 90 or 95 percent, it passes through several stages of concentration as essentially boiling conditions. There is little hydrocarbon left in the acid in this operation. The most corrosion-resistant materials available must be used in these operations because of the severity of the temperatures and concentrations. Hastelloy D, Corrosiron or Duriron, lead, acid brick, and carbon have been employed at different points in the system, depending upon the exact conditions. Steel and cast iron are satisfactory after concentration and cooling. In one installation, a valve of the chrome-nickel type alloyed with copper, silicon, and molybdenum was used with fair success in 75 percent acid at 275° F., but this alloy does not compare in corrosion resistance, under these conditions, with the high nickel-silicon and the high silicon-iron alloys.

Summarizing these various plant experiences by different types of operations gives a somewhat more comprehensive picture of what can be expected of a number of different metal alloys under different conditions of concentration and temperature. Such a summary is presented in Figure 3.

### Controlling Sulphuric Acid Corrosion

Corrosion from sulphuric acid may be controlled by chemical means, by changes in operations, or by mechanical and metallurgical means. More often than not, it is impossible to employ either one of the first two means because of some interference with the petroleum process, so that it becomes necessary to rely on mechanical and metallurgical means. To attain the maximum accomplishment by this method, mechanical design and maintenance must provide the most suitable materials for satisfactory mechanical operation, and metallurgical assistance must be used for the selection of materials which are best from a corrosion standpoint.

In the discussion on experiences, little or no mention was made of materials such as stoneware, porcelain, silica, and plastics, all of which have good corrosion resistant properties. These materials, except for the plastics, are all very fragile and for that reason are not attractive to a process in which inflammable materials are involved, and in which high pressures must sometimes be used. The use of plastics is limited to low temperatures and concentrations.

### Limitations of Various Materials

This is one of the principal reasons that so much difficulty is experienced with this sulphuric acid corrosion problem. The refiner is always endeavoring to find and use

materials which have good strength and high ductility as well as good corrosion-resistant properties. Almost invariably, however, it seems that the constituents in an alloy or other material which will make it resist the corrosive effects of sulphuric acid under severe operating conditions, at the same time lower the strength and ductility of that material. If there were not the economical and material availability limitations in addition to these, it might be possible to accomplish all desirable characteristics in one or a few different metals or alloys. As long as these limitations are present, however, it will be necessary to use a great many different metals and alloys, and some non-metallic materials.

In making selections of different materials, one should be guided to a large extent by past experience in similar plant operations. Laboratory data can be relied upon only to a limited extent and, therefore, extensive pertinent records of the actual operating unit experiences are essential. It is well to keep accurate accounts of comparative service life of different materials with specific reference to exact operating conditions. This is highly important, since repetitive replacements of unsuitable materials makes for very costly operations, which may actually reduce profits so much as to make a process unattractive.

In order to gain more and more knowledge of the corrosion resistance of available materials, actual field tests should be made continually by installing test samples or preferably test pieces of equipment such as valves, piping, and possibly pumps. Such testing of different materials will enhance our general knowledge of this subject and enable us to make better future installations for lower overall costs.

The importance of testing materials under plant operating conditions and keeping accurate accounts of plant operating data are stressed more than laboratory data. The reasons for this are quite obvious, for many existing laboratory data are seen that conflict with actual plant experience. This, however, does not mean that laboratory data can be dispensed with, because they certainly have their place in this work. Chemical and metallurgical laboratories must be used and relied upon to furnish a lot of basic data.

In addition, every opportunity should be taken to exchange information on corrosion from sulphuric acid in different locations and under different conditions. Such an exchange of experience, ideas, and suggestions oftentimes is extremely helpful. Coincident with this, of course, benefits can be obtained through the experience of those engineers and technicians whose business it is to work only with this type of problem.

Through such means as these, a more enthusiastic active participation in mechanical and metallurgical means of control can be developed.

# New Records Set During NACE Conference, Exhibit; Plans Launched for 1948 Corrosion Show

**Highlights of the April 7-10, 1947, All-Corrosion Conference and Exhibition sponsored by NACE were the presentation of two awards for achievement in corrosion research and engineering, and the installation of new officers. Thirty-four technical papers were presented during the eight symposia, and 39 exhibitors displayed their corrosion-resistant and mitigating services, materials, equipments and devices. New attendance records were established.**

SIX HUNDRED thirty-one corrosion engineers, who registered, and double that number who did not, attended the third annual all-corrosion Conference and Exhibition sponsored by the National Association of Corrosion Engineers at the Palmer House, Chicago, April 7 through 10. While the number of official registrants established a new attendance record, conservative estimates placed the top day's attendance at 1250, which greatly exceeded pre-Conference predictions of the most optimistic. Officials and Exhibitors alike expressed themselves as well pleased, and visitors were unanimous in the opinion that, " . . . this is the best show as yet staged by NACE." All of which attests to the great growth of the Association in its few short years of existence.

### Overflow Audiences at Various Symposia

Each of the eight symposia attracted an average of 200 listeners. Several sessions were presented before overflow audiences. Lively discussions followed each paper that was read. And the Exhibition arena was filled during all open hours.

So intense was the interest in this year's show, that the great influx of early arrivals caused officials to open the registration desk Sunday—24 hours ahead of schedule. All day Monday and Tuesday, long queues of persons waited their turn to register, and Wednesday saw only a slight shortening in length of the lines before the registrars. Even on the final day of the session they still came.

Glamour and progress went hand and hand during the Exhibition—39 eye-arresting displays occupying 51 booths gave evidence of the great strides made in recent years to put down corrosion's toll.

In contrast, not glamour, but progress marked the Conference and Technical sessions. Thirty-four technical papers were presented, outlin-

*President*

**G. R. OLSON**
United Gas Pipe Line
Corporation

# NACE

## *Officers for 1947-48*

*Vice President*

**F. L. LaQUE**
International
Nickel Company

*Treasurer*

**O. C. MUDD**
Shell Pipe Line
Corporation

**T. L. HOLCOMBE**
Dearborn
Chemical
Company

**M. G. FONTANA**
Ohio State
University

# *New Members of the Board of Directors*

**H. M. TRUEBLOOD**
Bell Telephone
Laboratories

**H. H. ANDERSON**
Shell Pipe Line
Corporation

**ARTHUR SMITH, JR.**
**Named to Fill Vice-President LaQue's Unexpired Term as Director**

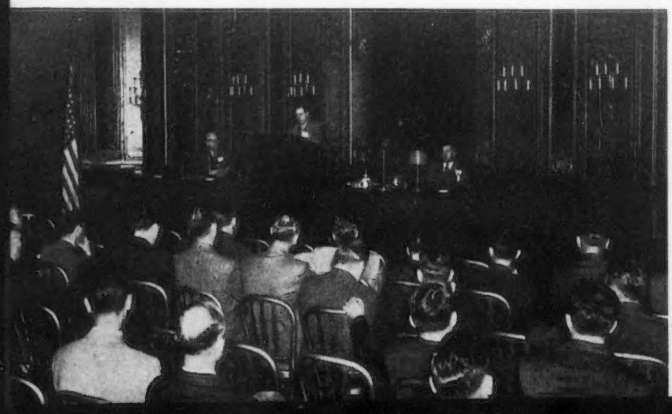
ing the latest developments and findings in the field of corrosion research.

The Exhibition and technical session reflected the great work being done by this country's leading industrialists to put down corrosion, and attested to the valuable part played by NACE in bringing about cooperative work toward that end by 96 companies—corporate and associate members — contributing toward continued expansion of the Association.

The Conference and Exhibition officially opened Monday, with Registration in the morning, and the General Assembly, with F. J. McElhatton, Panhandle-Eastern Pipe Line Company, presiding, in the afternoon. H. H. Anderson, Shell Pipe Line Corp., Houston, and Tom L. Holcombe, Dearborn Chemical Co., Shreveport, La., were guest speakers. Two concurrent symposia were held each morning, starting at 9:00 A. M. Tuesday, except Wednesday, when dual sessions were also held during the afternoon.

## Record Crowd Witness Installation of Officers

Upwards of 400 persons jammed the Grand Ballroom of the hotel for Wednesday's annual NACE banquet, which was highlighted by introduction of the new officers and directors, presentation of the newly established awards in the field of corrosion science and engineering, and an address by Edwin Vennard, Middle West Service Co., Chicago.



**President McElhatton at rostrum during General Assembly.**

Mr. McElhatton, retiring president, introduced the incoming officers: G. R. Olson, United Gas Pipe Line Co., Shreveport, La., President; F. L. LaQue, International Nickel Co., New York, Vice President; O. C. Mudd, Shell Pipe Line Corp., Houston, re-elected Treasurer; and the new directors, Mars G. Fontana, Ohio State University, Columbus, Ohio; H. M. Trueblood, Bell Telephone Laboratories, New York; and Mr. Holcombe and Mr. Anderson; and Arthur Smith, Jr., Dow Chemical Co., Midland, Mich., who was named to fill Vice President LaQue's unexpired two-year term as director.

**McDonald Presents Awards**

Following introduction of the officers, H. H. McDonald, chairman of the NACE Awards Committee, presented the Willis Rodney Whitney Award in the Science of Corrosion, and the Frank Newman Speller Award in Corrosion Engineering. Dr. Speller was present to receive the award named in his honor, but Dr. Whitney was forced to forego that pleasure due to advanced years which precluded his traveling from the East to Chicago. In his absence, Dr. H. H. Uhlig, Massachusetts Institute of Technology, accepted the award for transmission to the honoree.

**A. B. CAMPBELL**
**Re-Elected Executive Secretary**

Hardly had the dust settled on the Conference and Exhibition, when officials launched plans for the 1948 session. It was announced that next year's show will be held in St. Louis April 5 through 8. And again, exhibition, technical sessions and Conference will be held under one roof in the Jefferson Hotel.

**Waiting to register. Note: Time is A.M.**

# NACE Awards

## Willis Rodney Whitney Award in the Science of Corrosion

Presented to

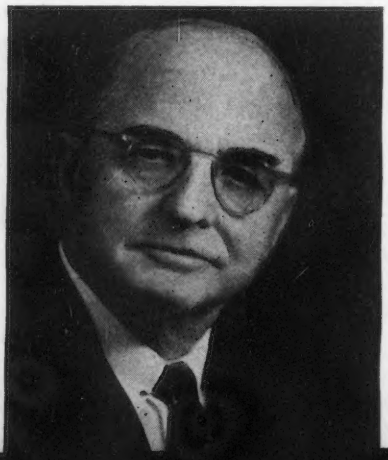
**DR. WILLIS RODNEY WHITNEY**

"For outstanding achievement in fundamental work in the corrosion field through establishing the electrochemical theory of corrosion."

ALTHOUGH Dr. Whitney has done a great deal of practical and theoretical scientific research work, his most notable achievement has been the creation and development of the General Electric Research Laboratory, one of the first and most famous industrial laboratories in the United States. He has received numerous scientific medals and awards, and honorary degrees.

A native of Jamestown, N. Y., he now resides in Schenectady. Dr. Whitney graduated from Massachusetts Institute of Technology in 1890 with a B. S. degree. In 1896, he received his Ph. D. from the University of Leipzig.

Dr Whitney taught at M. I. T. before he went to Schenectady in 1900 to establish the General Electric laboratory, and for a while, divided his time between the two. During this period, he completed his important work on corrosion at the Institute. This went back to his researches, starting in 1894, at Leipzig, where he had studied the then new science of electro-chemistry under Wilhelm Ostwald. Dr. Whitney's classical paper on electrochemical principles of corrosion was published by the American Chemical Society in its 1903 Journal.



Previously it had been supposed that iron would not corrode unless carbonic acid, or some other acid, were present. Dr. Whitney, however, showed that even pure water corrosion can be initiated by the oxygen present. Iron dissolves in the water by replacing oxygen, which deposits on the metal. Then, if oxygen is present, iron and oxygen unite, and corrosion, or rusting proceeds. This new concept of the mechanism of corrosion provided the basis for further work, which has reduced the losses due to rusting.

In 1928, Dr. Whitney was elected Vice President of General Electric, and resigned in 1940. Since, he has been an Honorary Vice President of the Company. A member of a long list of scientific and engineering societies, he is a past president of American Chemical and Electrochemical societies.

# For 1946

## Frank Newman Speller Award in Corrosion Engineering

Presented to

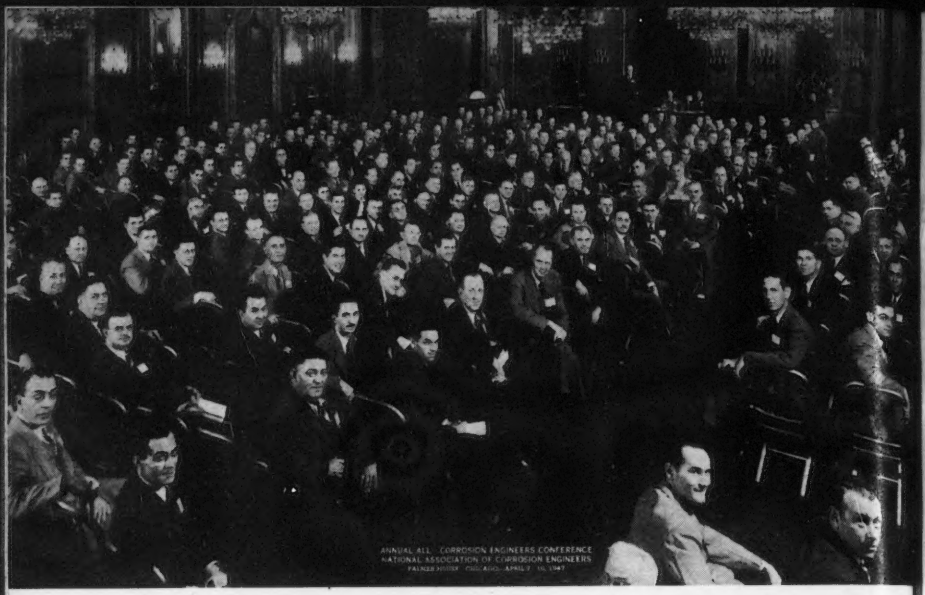
**DR. FRANK NEWMAN SPELLER**

"For application of fundamental corrosion studies to practical engineering problems."

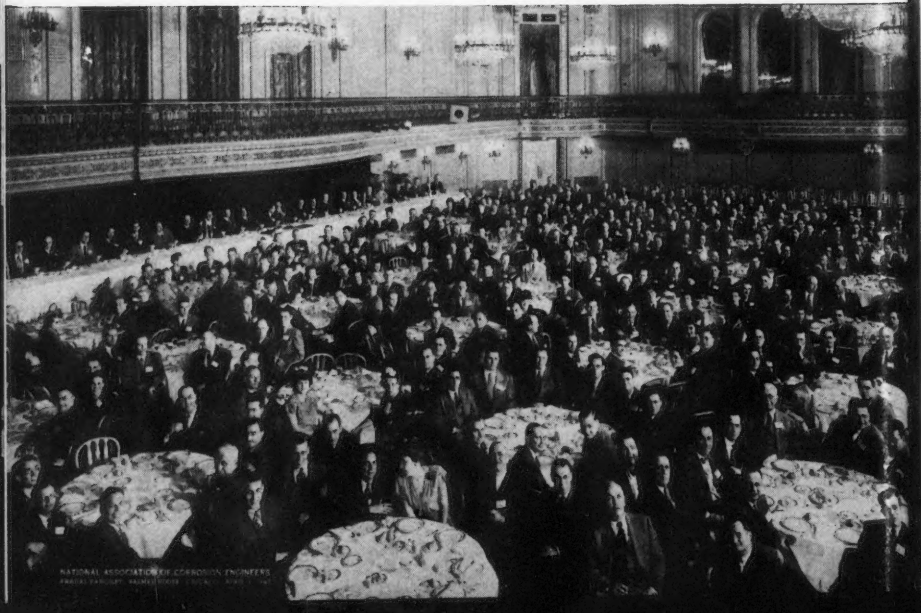
DR. SPELLER is world famous for his extensive corrosion investigations. He is the author of many technical papers, mainly in the field of corrosion and metal protection. His book, "Corrosion-Causes and Prevention," now being rewritten for the third edition, is known to all workers in the field of corrosion.

Dr. Speller was born in Toronto, Ontario, Canada, January 1, 1875. He was graduated from the University of Toronto with a Bachelor of Applied Science degree in 1894. After graduation he was awarded a Fellowship at the University, and then went to the Pittsburgh area to work in the Chemical Laboratory of the Carnegie-Illinois Steel Corporation at Homestead, where he later became Assistant Metallurgical Engineer of the National Tube Company in McKeesport. In 1904, he was made metallurgical engineer of the National Tube Company in Pittsburgh, in which capacity he served until 1926. He was then promoted to Director of the Metallurgical and Research Department of the National Tube Company, a position he held until 1940, when he went into private consulting work.

Recognition has been given Dr. Speller's attainments by the award of an honorary D. Sc. degree from the University of Toronto in 1923, the Longstreth Medal of the Franklin Institute in 1927, the Medal of the American Iron and Steel Institute in 1931, and an honorary membership in the American Society of Testing Materials in 1946. In 1934, he delivered the annual Hower Memorial Lecture of the American Institute for Mining and Metallurgical Engineers, in which he discussed the "Corrosion Problem with Respect to Iron and Steel." He is an active participant in the work of several technical societies, including the National Association of Corrosion Engineers, the Electrochemical Society, and the American Iron and Steel Institute.




# Conference Scenes



# Corrosion Previews

## Soluble Silicates for Corrosion Inhibition in the Oil Industry

By WM. STERICKER, Philadelphia Quartz Co., Philadelphia, Pa.

The addition of small amounts of sodium silicates containing stable hydrated silica to either fresh water or brine gives a high degree of protection against corrosion. The use in salt water disposal lines is illustated by a case history which showed that application of 40 ppm will give 80 percent protection. This is approximately four gallons of silicate solution per thousand barrels of brine for protection of a salt water disposal line. The silicates are found to form a film over existing corrosion, to aid in flushing away loose material, and to build up a coating which is effective in greatly retarding corrosion attack.

One line, treated with sodium silicate, showed the brine clear after 30 months operation, whereas the brine formerly was turbid; pipe scale was reduced and harded, and leakage halved from former totals. Silicates are also useful in preventing the pick-up of iron by brine, thus protecting the face of the formation in input wells of salt water disposal systems.

Improvement in one sucker rod string feeding silicates to the well through annulus showed corrosion loss to be one-tenth that formerly experienced, with tubing failure reduced 50 percent.

The use in fresh water is illustrated by the addition to the general cooling water system of a large refinery. The protective film developed more slowly on this system. Eventually, however, maintenance was reduced from the full time of a three-man crew to practically none.

From these and other field tests, conclusions are drawn which it is hoped will serve as guides in the use of sodium silicates to inhibit corrosion elsewhere.

Mr. Stericker was born in Fort Collins, Colorado, December 1, 1895. He graduated from the University of Wisconsin in 1917 with a B. S. degree in Chemistry.

Wm. Stericker

From 1917 to 1919 he was with Westinghouse Lamp Co. at Bloomfield, N. J., where he had his first experience in troubleshooting and developed an interest in colloidal materials. In 1919 he became an Industrial Fellow at Mellon Institute of Industrial Research. This was a part-time fellowship which permitted graduate work at the University of Pittsburgh, resulting in a Ph.D. degree in 1922. Following this he went with the Philadelphia Quartz Co., donors of the fellowship. He has been with that company since.

His primary scientific interests are in the properties and uses of soluble silicates and their derivatives. This has led to investigations of detergents, corrosion inhibitors, cements, bleaching, coatings for welding rods and roofing granules, adhesives, paper, etc.

He has been active in the Philadelphia Section of the American Chemical Society, of which he is a councilor and past chairman. He is also a member of Franklin Institute and the American Electroplaters' Society.

## Chimney Corrosion Resulting From Gas Fired Furnaces

By G. B. JOHNSON, Minneapolis Gas Light Co., Minneapolis, Minn.

This paper contains a brief review of the chemical and physical effects of various products of corrosion that are found in flue gases from gas fired equipment, and the effects of dewpoints, other gases and chimney construction on the concentration of these corrosion products in the chimney. Minneapolis has 42,000 gas fired heating jobs installed, and has used the following types of liners: Wilder metal with asphalt chromium emulsion coating; Vitreous enamel on steel; Plastic on steel; Aluminum: Plastic coating on aluminum. The number of these various types of liners installed, and the percentage that have corroded are outlined. The corroded liners are segregated into groups as to types of heating equipments (gas designed or conversion), types of heating plants, outside or inside chimneys, etc. Other effecting data such as $CO_2$, stack temperatures, and other fuels burned and vented into same chimney, analysis of gas, etc., are given. The above data are tied in with laboratory tests that have been conducted by various gas companies.

The author graduated from University of Minnesota in 1933 with a degree of Bachelor of Chemical Engineering. Since graduation he has worked for the Minneapolis Gas Light Company in the following capacities: Chief Chemist, Superintendent of Production, Manager of Suburban Division, Assistant Sales Manager, and Manager of Customer Service.

G. B. Johnson

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## Control of External Corrosion On Plantation Pipe Line

By ALAN C. NELSON, Plantation Pipe Line Company, Atlanta, Georgia.

Laid in soil which showed extremely low as well as extremely high resistivities, the line was coated only through the "hot spots," the remainder of the line being laid bare. Four classes of corrosion were recognized and studied separately; they were stations, tank bottoms, main line sections, and drainage problems.

At stations, resistivity was found to be lowered under the slag walks and clear areas established at valve wheel control points.

Rectifiers were used in cathodic protection where low-resistivity soils were traversed, and there gave excellent results. When the soil resistivity was high, anodes of either magnesium or aluminum were

*(Continued on next page)*

Alan C. Nelson

# Effect of Carbide Structure on the Corrosion Resistance of Steel

By R. W. MANUEL, Phillips Petroleum Company, Bartlesville, Oklahoma.

R. W. Manuel

Microscopic study of corrosion phenomena in tubing is found to offer a possible indication of the reason for the type of corrosion usually called "ringworm."

In most oil-well corrosion, solid corrosion products form on the surface of the steel. The resulting corrosion film is generally protective in nature, but failure of the film in certain areas leads to localized attack. The critical factor most often involved in local failures of the corrosion film is the carbide structure of the steel from which it was formed. Lamellar pearlite increases corrosion resistance. Distortion of the pearlite structure by heating subsequent to its formation impairs corrosion resistance. Spheroidization of the pearlite is very detrimental. In quenched and tempered structures, corrosion resistance decreases as the degree of spheroidization of the carbides, during tempering increases. The effect of carbide structures on corrosion resistance is important enough to deserve further study, since the corrosion rate on the locally attacked areas is often 10 to 100 times as great as on the rest of the surface.

The author has been a metallurgical engineer with the Phillips Petroleum Company, since April, 1946. Born March 13, 1916, in Taft, Texas. He attended public schools in Kansas City, Mo., and received his degree of B.S. in chemical engineering from the University of Kansas, and the Illinois Institute of Technology. Formerly associated with the Crane Company, Chicago, (1937-42), Goodyear Aircraft Corp., Akron, Ohio, (1942-43), he has engaged in research and engineering development work on problems of corrosion, electroplating and metallurgy.

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*(Continued from preceding page)*

used, due to the difficulty of establishing ground beds in such soils.

In high-resistivity locations, tank bottoms were protected by burying a magnesium anode at each of the four water draw-off points; while in low-resistivity areas nine anodes were spaced around each tank and it was insulated from the manifold with special gaskets in the flange unions.

The method for combatting drainage currents from an electric line were discussed, and the utilization of a half-cell rectifier as a means of controlling frequent and destructive current reversals was described.

The author, a corrosion engineer, was born Jan. 4, 1911, in Northport, Mich. He received his B.S. degree in chemical engineering from Michigan State College in 1932. After seven years in the Technical Division of the Pure Oil Company, he was transferred to the Southeastern Pipe Line Company, then under construction. He served first as Chief Chemist, then Chief Dispatcher until 1945, at which time he became associated with the Plantation Pipe Line Company to work on the control of external corrosion.

**Biographies of other speakers, and abstracts of the papers they presented during the NACE Corrosion Conference, April 7-10 at the Palmer House, Chicago, were published in the February and April editions of CORROSION. Many of these papers after being processed by the Publications Committee, will appear in full, together with illustrations, in later editions of CORROSION.**

General Interest

# Correlating Committee on Cathodic Protection Completes Organization

SINCE AUGUST, 1946, work has been in progress to organize the Correlating Committee on Cathodic Protection, an inter-industry activity to publicize and to improve procedures for handling problems arising from cathodic protection of pipe lines, communications cables, railroad signal systems and other buried metal structures. Cathodic protection is an effective retardant of soil corrosion which is damaging industrial plants to the extent of at least 200 million dollars per annum. To date eleven nation-wide organizations have taken formal action to join in the activity and have each named two representatives on the committee.

The member organizations are Association of American Railroads, American Gas Association, American Petroleum Institute, American Public Works Association, American Water Works Association, Bell System, Edison Electric Institute, International Municipal Signal Association, Inc.; National Association of Corrosion Engineers, United States Independent Telephone Association, and Western Union Telegraph Company. Chairman of the Committee is H. H. Anderson, Vice President, Shell Pipe Line Corporation, and Secretary is F. E. Dolson, Engineer, St. Louis County Water Company.

As originally announced, the initial objective will be achieved by a program of education and assistance to be accomplished through the drafting of general and technical bulletins. It is planned that these bulletins will be published and distributed by each industry to its own membership. The titles of the four bulletins, and the representatives appointed by the Chairman to prepare each, are as follows:

## I. GENERAL INFORMATION

| Active | | Associate | |
|---|---|---|---|
| NACE | O. C. Mudd, Chm. | API | L. F. Scherer |
| AAR | R. B. Amsden | AGA | Guy Corfield |
| AWWA | A. R. Davis | APWA | R. J. Kuhn |
| EEI | M. W. Ghen | Bell | K. L. Maurer |
| USITA | L. C. Burden | IMSA | J. D. Southwell |
| | | W-Un | J. F. Blain |

## II. NOTIFICATION PROCEDURE

| Active | | Associate | |
|---|---|---|---|
| API | L. F. Scherer, Chm. | AGA | F. J. McElhatton |
| AAR | A. E. Archambault | APWA | * |
| AWWA | F. E. Dolson | Bell | J. M. Standring |
| IMSA | Frank Smith | EEI | T. G. Hieronymus |
| USITA | L. W. Hill | NACE | O. C. Mudd |
| W-Un | J. G. Blain | | |

(*) To be named.

## III. TECHNICAL PRACTICES

| Active | | Associate | |
|---|---|---|---|
| Bell | K. L. Maurer, Chm. | AAR | R. B. Amsden |
| AGA | Guy Corfield | API | H. H. Anderson |
| APWA | R. J. Kuhn | AWWA | A. R. Davis |
| EEI | T. G. Hieronymus | IMSA | Frank Smith |
| NACE | M. C. Miller | USITA | L. C. Burden |
| W-Un | Orris McGinnis | | |

## IV. JOINT INSTALLATIONS

| Active | | Associate | |
|---|---|---|---|
| AGA | F. J. McElhatton, Chm. | AAR | A. E. Archambault |
| API | H. H. Anderson | AWWA | F. E. Dolson |
| APWA | * | EEI | M. W. Ghen |
| Bell | J. M. Standring | NACE | M. C. Miller |
| IMSA | I. D. Southwell | USITA | L. W. Hill |
| | * To be named. | W-Un | Orris McGinnis |

Although the Committee expects to promulgate quite specific suggestions for handling various types of situations, it will refrain from dealing with any immediate local problems. It proposes also to work in harmony with existing Metropolitan Electrolysis Committees whose present effective work with cathodic protection is recognized and commended.

**According to information received in the National Association of Corrosion Engineers' headquarters from a source believed to be reliable, all members of the Association who reside and work in Texas City escaped the blasts and fire which devastated that Texas city April 16-19. Those members of NACE who reside in Texas City are: P. E. Darling and M. C. Forbes, of the Pan American Refining Corporation; Dan L. Dodds and Joseph D. Millender of Republic Oil Refining Company; Edwin Jewell and H. E. Morris, of Monsanto Chemical Company; and A. R. Pettyjohn, of the Carbide and Carbon Chemical Corporation. According to NACE information, there exists no record of these persons as hospitalized, deceased, registered as evacuees in local Houston hospitals, or evacuation centers.**

**Offers to establish** 12 one-year fellowships in the fields of science and engineering have been made by Humble Oil & Refining Company to five leading universities in the Southwest and South and to Massachusetts Institute of Technology. Three fellowships, one each in geology, chemical engineering and chemistry, have been offered to the University of Texas; one each in civil engineering and mechanical engineering were extended to Texas A. & M. College; one each in physics and chemistry to Rice Institute; one in petroleum engineering and one in geology to both the University of Oklahoma and Louisiana State University; and one in chemical engineering to M. I. T. The fellowships will pay the holders the sum of $1,250 per academic year, and in addition, the fellowships in geology will provide an extra $500 to cover field work in the summer. Recipients of the fellowships will be students enrolled in Masters or Doctors degree work, and selection will be entirely in the hands of the universities.

**Battelle Memorial Institute,** Columbus, Ohio, will appoint a limited number of predoctoral fellows and post-doctoral associates to conduct investigations in industrial research at the institute. The program will open in the summer or fall of 1947.

**Stevens Institute of Technology,** Hoboken, N. J., has signed a contract with the U. S. Office of Naval Research to study motion of atoms in metals under stress.

**A project** for the study of corrosion by oxygen and carbon dioxide on the surfaces of light metals and alloys, to be conducted by Pierre van Rysselberghe, professor of chemistry, has been awarded to the University of Oregon, Eugene, by the Office of Naval Research. John M. McKee and Armin H. Gropp will assist Mr. Rysselberghe in carrying out the one-year, $10,000-program.

## Personals

**J. M. Bialosky,** associate metallurgist with the Armour Research Foundation, Chicago, is joining the research staff of the Carnegie-Illinois Steel Corp., Pittsburgh, Penn. Mr. Bialosky has been doing research in the corrosion field since receiving his B. S. degree in Chemical Engineering from the Case School of Applied Science.

**Admiral Ben Moreell,** for the past several months president and director of the Turner Construction Co., New York, has been elected board chairman, chairman of the executive committee and president of Jones & Laughlin Steel Corp., Pittsburgh, Penn. He succeeds H. E. Lewis, who retires because of ill health, but continues as a director and member of the executive committee.

**David L. Fiske** has resigned as secretary of the American Society of Refrigeration Engineers to undertake consulting and other activities in the field of his specialty, market research in refrigeration. Mr. Fiske had held the post of ASRE secretary for 20 years. A graduate mechanical engineer from MIT in 1920, Mr. Fiske received his master's degree in thermodynamics from the University of Illinois, and a Ph. D. in industrial engineering from Columbia University. His study, "The Demand for Refrigeration," has become a common reference for information on the economics of the industry.

**Harry K. Ihrig,** director of the laboratory, Globe Steel Tubes Co., Milwaukee, Wis., was presented the Robert W. Hunt Award during the annual meeting of the American Institute of Mining and Metallurgical Engineers, in recognition of his paper, "The Effect of Various Elements on the Hot-Workability of Steels."

**W. L. McCracken** has assumed new duties as director of research and manager of alkal manufacturing with the Detrex Corp., Detroit, Mich.

**The Dorr Company** has sold its interest in the Electro Rust-Proofing Corporation, of 1 Main Street, Belleville, New Jersey, to the Wallace & Tiernan Company of Newark, New Jersey.

## New Products

**Tretolite Company,** St. Louis, Missouri, announces the development of a new class of reagents for the prevention of corrosion of oil and gas well equipment. Designated as "Kontol Corrosion Preventives," it is claimed these inhibitors have been shown by laboratory and field testing to be effective in materially reducing corrosion in either pumping or condensate wells.

Prior to 1942 the corrosion of con-

densate well equipment was virtually unrecognized, but lately it has assumed a position of major importance in the economics of condensate well operation. Recent experience indicates that with wells produced at pressures above 150 psi and at reservoir temperatures above 160° F., corrosion may be serious if more than 0.2 percent $CO_2$ by volume is present. Extensive field testing has indicated Kontol 115 Corrosion Preventive especially effective in inhibiting corrosion in these wells.

Kontol 115 is a non-toxic, oil soluble, nearly odorless liquid which readily lends itself to well treatment. There is no tendency toward plugging of either the formation or well tubing by its use, since Kontol 115 does not show any reaction with salts carried by the brine, nor does it raise the pH of the brine with the possible resultant deposition of calcium, or magnesium scales. Although oil soluble, Kontol 115 is surface active and builds up a thin film on the metal surface which protects the metal from corrosive elements in either brine or condensate. Since it is a concentrated inhibitor, only small volumes of Kontol 115 are required to maintain this film, and thereby effectively inhibit the corrosion of well equipment.

Kontol 115 is now being employed commercially by various producers with good results, and with no harmful effects becoming apparent after approximately a year's continuous use.

**Dehumidification** machines, used widely in the Navy's fleet preservation program, known as Operation Zipper, are now available to industrial and commercial users, it was learned from Pittsburgh Lectrodryer Corp. in Pittsburgh. The firm recently completed the major portion of its Navy contracts and cleared its production lines for nongovernment orders, George L. Simpson, vice president and general manager of the organization, revealed. Prewar equipment found its widest use in metallurgical and chemical fields and in the oil and gas industry. However, successful use of the improved machines in the fleet program opened new and potentially greater markets, according to the company's research department. It solves problems of any number of industrial and commercial organizations confronted with the preservation of materials and equipment held in storage.

# Corrosion Abstracts

**Atmospheric Corrosion Tests on High Chromium Steels.** W. O. BINDER and C. M. BROWN. Steel Processing, **32,** 565-571 + (1946) Sept.

Presents quantitative data on marine and industrial atmospheric corrosion tests on a series of steels containing additions of chromium in amounts from 0 to 18 percent. Gives results of atmospheric corrosion tests on cold-rolled austenitic chromium-nickel and chromium-manganese-nickel steels of the type suitable to obtain light-weight construction.—BLR.

**Weathering—Appreciation and a Study.** G. D. CHAPMAN, Light metals, **9,** 196, 593-608 (1946) Nov.

The effects of atmospheric corrosion in a number of cast light alloys are reviewed and illustrated by some experimental work. Typical examples of the following groups of alloys were chosen for exposure: Aluminum-silicon; aluminum-silicon-copper; aluminum-copper, and aluminum-magnesium. Results of the weathering tests are summarized. The possibility of using X-rays to demonstrate the type and degree of corrosion is demonstrated. 10 illustrations.—AER.

**Phosphate Coating of Aluminum.** R. C. GIBSON and W. S. RUSSELL, Parker Rust-Proof Co., Ind. Eng. Chem. **38,** 1222-27 (1946) Dec.

A process is described which produces on aluminum and its alloys, either in sheets or castings, from a solution containing zinc phosphate, nitrate, and fluoborate, a paint-holding phosphate coating similar to that given iron, steel, zinc, and cadmium surfaces by Bonderite processes. In addition, it also coats zinc and steel and their alloys, an advantage to manufacturers who may have mixed production of these metals. This process requires no electricity, may be applied by spray or immersion in mild steel equipment and is readily adapted to conveyor production methods. Outdoor exposure tests, as well as accelerated salt-spray, humidity, and soak tests, show the improved results obtained by converting the surface of aluminum alloys to a stable, nonmetallic, finely crystalline phosphate coating prior to painting, to inhibit corrosion and increase the adhesion and resultant durability of applied organic finishes. This coating permits the use of a variety of paints which cannot be used effectively over untreated aluminum alloys.—CEC.

**Corrosion of Watthour Meters in Ocean Beach Areas**, A. D. TRION and R. M. STEVENS, Southern California Edison Co. Elec. World, **125**, 17, 63-65 (1946).

The meters were in such an advanced state of corrosion that replacement of bases, terminal chamber covers, and other parts were necessary. Glass covers cracked owing to pressure (increase volume) of corrosion salts. Corrosion was accentuated by salt-laden moisture, and dissimilar metals in close proximity. Installations had been in service for 1.5 to 5 years. Stainless steel and anodized aluminum are to be tried.

**Effect of Structural Changes in Steel on Fatigue Life of Bearings.** Steel, **119**, 68-70, (1946) Sept. 30.

Reports metallographic observations of subsurface changes in structure and their effect on fatigue life of high carbon and higher alloy steels used in completely hardened martensitic state, and subjected to compressive loads.

**Some Corrosion Problems Encountered in Steam Plant Operation.** J. A. KEETH, Kansas City Power & Light Co. Corrosion, **2**, No. 2, 101-123 (1946) June.

Types of corrosion prevalent in steam power plants and some preventive methods are discussed. The following are covered: attack by dissolved gases in liquids; corrosion due to decomposition of steam; attack by stack gases; furnace slag attack; corrosion fatigue; corrosion-erosion; miscellaneous, including graphite corrosion, copper plating of steel, corrosive liquids, electrochemical causes; and caustic embrittlement.

**Roller Coating Aluminum.** HERSCHEL E. POST. Organic Finishing, **7**, 43-44 (1946) Sept.

Brief description of technique, which, together with new primer, made it possible for a crew of six men to process 350 aluminum sheets per hour. Before roller-coater devised, same crew turned out manually from 18 to 20 sheets an hour.—BLR.

**Hot-Dip Galvanizing Practice.** WILLIAM H. SPOWERS, JR., Steel, **119**, 149-150 + (1946) Sept. 23; **119**, 134 + (1946) Oct. 7.

Discussion of dross contamination shows that each of the four causes enumerated is closely related and, to a large extent, controlled by the type and design of installation. Discussion of preparation of solutions for galvanizing give details of results of variations in quantities of salts and techniques.—BLR.

**Aluminum Paint Vehicles and Their Effect on Leafing.** J. WRIGHT, Official Digest, 393-397 (1946) Sept.

Results of test made to determine those characteristics of the usual types of aluminum paint vehicles, which contribute to the proper leafing of paint grades of aluminum pigments, either powder or paste.

**Insecticidal Paints.** W. CARR, Paint Manufacturer, **16**, 280-282, (1946) Aug.

Reviews information relating to the use of DDT and Gammexane in paints as insecticides and for control of salt-water fouling method for analysis of paints for their insecticidal content.

**Protective Action of Lead Compounds.** J. E. O. MAYNE, J. Soc. of Chem. Ind. Transactions and Communications, **65,** 196-204 (1946) July.

Distilled water may be rendered non-corrosive by contact with lead powder, litharge and red lead. Little or no inhibition was obtained from lead peroxide, lead sulphate, lead chromate, basic lead sulphate, basic lead carbonate, iron oxide and titanium oxide. So long as the lead pigment was sufficiently basic to form soaps, it yielded a paint film which was capable of making water non-corrosive. Mechanism of inhibitor, methods for development of most satisfactory vehicle, and unsolved problems are discussed.

**Stoving and Heat-Resisting Finishes.** ROYDON L. FROST, Paint Manufacture, **16,** 294-300 (1946) Aug.

Gives indication of some of the problems involved in their preparation, together with notes on the properties of these finishes, and some thoughts on possible formulation of the future.

**Effect of Spray Technique Upon the Porosity of Metal Coatings.** A. GLAZUNOW and L. JENICEK, Paint, Oil & Chem. Rev., **109,** 40 (1946) Oct. 3.

Describes experiments in which variations in gun movement, distance between nozzle and painted surface, air pressure, and number of coats were studied. Also describes "electrographic" method for determination of continuity of coatings. Results indicate that spraying several coats in order to ensure a continuous coating may result in a considerable waste of material and that conditions should be adjusted to ensure a continuous coating with one spray application.

**Treatment of Iron and Steel Used In Building Construction.** A. R. KING, Paint Manufacturer **16,** 283-287 (1946) Aug.

Recommends use of a metallic coating and two coats of paint, or a phosphate coating and three coats of paint. Discusses conditions affecting durability, methods of application and pros and cons of phosphating.

**Zinc Spraying.** JOHN HOWAT. Corr. & Mat. Prot. **3,** No. 7, 8-10 (1946) Aug.-Sept.

Lists results obtained by process and services in which metallizing with zinc have been used.

**Silicone Resins in Protective and Decorative Finishes.** J. R. PATTERSON, Paint & Varnish Prod. manager, **26,** 254-255 + (1946) Oct.

Discusses properties and applications of the various silicones for use in finishes.—BLR.

**Effect of Coefficient of Expansion of Ground and Cover-Coat Enamels on Thermal-Shock and Impact Resistance.** F. A. PETERSON and A. I. ANDREWS, J. Am. Cer. Soc. **29,** 288-295 (1946) Oct. 1.

Four antimony cover-coat enamels, four fluoride cover-coat enamels, and four ground-coat enamels were furnished to give varying coefficients of expansion. The enamels were applied to standard 2-quart pudding pans and were tested for thermal shock and impact resistance, using standard methods of the Enameled Utensil Manufacturers' Council. Results and conclusions are presented. Solubility resistance and reflectance curves for the enamels are also included. 15 references.—BLR.

**Drying Oils, Driers, and Varnishes.** C. W. A. MUNDY and J. H. GREAVES, Paint & Varnish Prod. Manager, **26,** 257+ (1946) Oct.

Review of recent work (since about 1943). 41 references.

**Deposition of Metal on Plastics.** E. A. OLLARD and E. B. SMITH, Plastics, **10,** 470-475 + (1946) Sept.

Discusses types of plastics; adhesion of the coating; plating process; cleaning the surface; waterproofing; bronze powder and graphite process; choice of graphite; use of copper powder; enhancing conductance of current; vacuum sputtering; vaporization in vacuo; and spraying. (To be continued.)

**Interim Descriptive Statement on the Leaching-Rate Test for Ships' Anti-Fouling Compositions.** Iron & Steel Inst., Advance Copy, Aug., 1946, 5 pages.

Small glass panels coated with anti-fouling composition are stored in sea-water and transferred periodically into the leaching apparatus, where they are subjected to agitation (by bubbling) in a definite amount of sea-water for a standard time; the toxic substances leached into the water are then determined. Determination by colorimetric methods (using a "Spekker" photo-electric adsorptiometer) of the small amounts of copper and mercury leached into the sea-water is described. Critical leaching rate for copper is about 10 micrograms/sq. cm./day. Rates for other anti-fouling compositions are being investigated.

**Evaluation of Protective Coatings.** D. A. HILLIARD, Organic Finishing, **7,** 31-33 + (1946) Sept.

Discusses various methods developed for controlling film thickness of test panels. Describes following resistance tests: hardness or mar, abrasion, moisture, salt-spray, outdoor exposure, soap, food acid and grease, heat, and production line conditions, and distensibility and adhesion.

**Nickel-Zinc and Nickel-Tin Corrosion-Resistant Metal Coatings.** L. C. CONRADI, Prod. Eng. **17,** 127-129 (1946) Sept.

Double-plated metals subsequently heat-treated to improve corrosion resistance. Plating materials, suitable thicknesses of plating and relative cost, together with typical data on effectiveness of corronizing from salt spray tests and information for use in design are discussed.

**Coatings for Fuel Oil Containers.** J. PIEPER, Paint, Oil & Chem. Rev., **109,** 40 (1946) Oct. 3.

Summarizes results of investigation of materials on an inorganic base, metallic coatings, air-drying organic coatings, linings of an organic nature, and baking or catalyst convertible type of organic coatings. Test panels were exposed to a solvent mixture consisting of 100 parts of gasoline, 100 parts of benzole, 70 parts of high strength alcohol, and 30 parts of methanol.

**Formulation of Anti-Corrosive Compositions for Ships' Bottoms and Underwater Service on Steel. Part II.** F. FANCUTT and J. C. HUDSON, Iron & Steel Inst., Advance Copy. Aug., 1946, 24 pages.

Describes raft tests of 127 newly formulated anti-corrosive paints comprising various combinations of eight different media, with mixtures of 13 different pigments. On the basis of the results, a paint pigmented with a mixture of two parts basic lead sulphate and one part each of white lead, Burntisland red, and barytes, and bound in a modified phenolformaldehyde/litho-oil medium recommended. Paints in a chlorinated-rubber medium were outstanding but certain technical difficulties need to be overcome before these can be used effectively on a practical scale.

**Corrosion of Light Metals and Its Prevention.** A. DOMONY, Banyasz. Kohasz. Lapok, **76,** 221-230 (1943); Chem. Zentr., **114,** No. 2 1846 (1943) J. Inst. of Met. & Metall. Abs., **13,** 252 (1946) July

Various types of corrosion (chemical, electrochemical and intercrystalline) occurring in light alloys, and the effect of alloying elements, impurities and heat-treatment are discussed. Protective methods described in detail; operating suggestions given for anodic oxidation, chemical oxidation, plating galvanizing and lacquering.

**Adhesion of Paint Films on Metal.** E. KARSTEN, Paint Manufacture, **16,** 304 (1946) Aug. Metals Rev., **19,** No. 11, 11 (1946) Nov.

Fourteen types of metal sheet were coated with six types of paint and then exposed to a salt-spray test. Adhesion values were obtained after 3, 10, and 18-day periods, and the paints were classified in order of decreasing adhesiveness; also, the metal surfaces were classified according to suitability as a base for paint films.

**Protective Coatings for Magnesium and Its Alloys.** OSRD Report 1462, PB 12144, 1943, 9 pp. (Bakelite Corp.) Elect. Manufacturing, **38,** No. 2, 194 (1946) Aug.

Preliminary investigation of protective coatings for magnesium alloys. A number of clear coatings were tested for their moisture-excluding properties. The best of these are to be tested further, with various corrosion inhibiting pigments incorporated in the coatings.

## CATHODIC PROTECTION

**Measurement of Cathodic Protection Currents in Submarine Pipelines.** W. R. HILL, Pet. Engr. **17,** No. 6, 168 + (1946) Mar.

The two electrical measurements to determine the minimum protective current density on a submarine pipeline are: 1) determination of the current at point "A," which is at the shore end of the line, and 2) measurement of the total voltage drop between the sea end of the line, or "B" and the shore end, or "A." The voltage drop between "A" and "B" can be made by using the telephone laid with the pipeline for ship-to-shore communication. These two measurements, together with the curves for estimating minimum current density, permit a reasonable estimate of the minimum current density at the sea end of the line.

## CHEMICAL CORROSION

**Some Case Histories of Corrosion Problems in Chemical Process Equipment.** W. Z. FRIEND and F. L. LAQUE, International Nickel Co.,

Trans. Am. Inst. Chem. Eng. **42**, No. 5-6, 849-862 (1946).

Principal factors which affect corrosion are listed. Reports of the investigation of several plant-equipment corrosion cases are given to illustrate methods sometimes required to solve such problems. Cases selected illustrate the effects of one or more corrosion factors. The cases reported illustrate the effect of aeration on reduction of dyestuff; effect of corrosive impurities in caustic soda; effect of carbon dioxide in steam; effect of an inhibitor; effects of velocity and contamination by corrosive products; effect of temperature; and effects of a combination of factors.—AER.

**Chemical Cleaning Takes the Bull Work Out of Scale Removal. I and II.** E. W. Feller and G. F. Williams, Dowell, Inc. Power, **90**, No. 9, 74-78 (1946) Sept.; No. 10, 71-74 (1946) Oct.

Use of hydrochloric acid (commercial, 28-32 percent hydrogen chloride by weight) is recommended for chemical removal of scale. Acid reactions are given for hydrochloric, nitric and sulfuric acids. Corrosion losses of Admiralty metal, mild steel and cast iron in 5 and 15 percent raw hydrochloric acid are graphed, and figures tabulated on corrosion loss of steel, cast iron, copper, stainless steel, brass, bronze and Admiralty metal in inhibited and raw acid (100° and 150° F.). Materials having inhibiting properties are listed and discussed. Scale analysis methods and typical acid-cleaning procedure are also discussed. Basic amounts of hydrochloric acid needed to dissolve various types of scale are listed. 44 references.

**The Time-Temperature Relation for the Solution of Zinc in Dilute Sulfuric Acid.** G. Nilsson, Tekn. Tidskr., **72**, No. 37, 65-68 (1942); Chem. Zentr., **114**, No. 1, 498 (1943); J. Inst. of Met. & Metall. Abs., **13**, 253 (1946) July.

The speed of solution of zinc in sulfuric acid was determined by the quantity of hydrogen developed. It varies with temperature, concentration and with the final quantity of zinc dissolved. The speed increases rapidly between 20° and 40° C., increases more slowly to a point then decreases and is the same at 70° C. as at 20° C. Reasons for the decrease in speed are structural changes, impurities on the cathodes, protective films formed on the metal, and more uneven attack by the acid. Addition of zinc sulfate has a greater retarding effect at 70° C. than at 20° C.

**Protection Against Corrosion of Apparatus for the Chemical Industry.** P. Bourgois, Chem. peintures, **6**, 171-177 (1943); Chem. Zentr., **114**, No. 2, 1035 (1943); J. Inst. of Met. & Metall. Abs., **13**, 255 (1946) July.

A review of conditions promoting corrosion (nature of the aggressive agent, operating temperature, etc.), and the physical and chemical properties of materials used for such equipment, including metals and metal alloys and such mineral products as acid-resistant brick and tile, concrete, cement, acid-resistant cements, glass, quartz and hydrocarbons.

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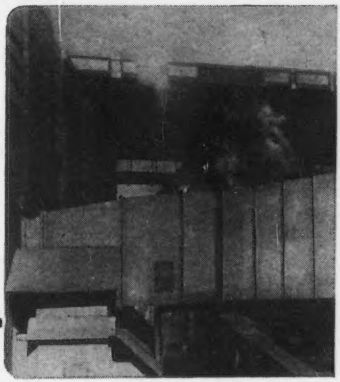

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## CORROSION TESTING

**Principles of Immersion and Humidity Testing of Metal Paints.** Inc. discussion. A. C. ELM, New Jersey Zinc Co. ASTM Bulletin **1946,** No. 142, pages 9-27, Oct.

Discusses: Designing a test; control of substrate uniformity; effect of panel size; effect of film imperfections; selecting a testing technique; and translation to practice. Many factors must be taken into account in designing and carrying out a test; such tests must be compared with a considerable background of practical experience with such tests, eliminating opinions formed on only limited experience.—CEC.

**Short-Term Weathering Test as a Criterion of Performance.** R. N. WHEELER, J. Oil & Colour Chem. Assoc., **29,** 171-181 (1946) Aug.

Reviews tests for flow and hiding power, brushability, film thickness, consistency, drying time, flexibility, and adhesion. Evaluates the salt spray test, humidity tests, and exterior durability tests as accelerated weathering tests.—BLR.

**Insulation of Dissimilar, Metal Faying Surfaces.** BERNARD W. FLOERSCH, Auto & Aviation Industries, **95,** No. 7, 37 + (1946) Oct. 1.

To determine the optimum organic insulation necessary for protection against galvanic corrosion in various dissimilar metal contacts, the series of tests reported in this article were conducted at the laboratory of the Ryan Aeronautical Company. Study specimens were fabricated and tested in a salt-spray cabinet. The tests were not correlated with actual service conditions but were designed to show the comparative corrosion resistance of definite dissimilar metal contacts having various finishing schemes. Among the dissimilar metals studied were 24S-T Dural, with cadmium-plated 1025 steel; AMC52S-H magnesium with 18-8 stainless steel; AMC52S-H magnesium, with 24S-T Dural and AMC52S-H magnesium, with 24S-H alclad. The test combinations which were prepared and given protective treatments are listed, and the conclusions reached in the investigation are set forth. Two illustrations.—AER.

## FUNDAMENTALS

**Experimental Study of Some Corrosion Phenomena of Zinc.** E. LAGRANGE, Metaux, Corrosion-Usure, **17,** 164-167 (1942); Chem. Zentr., **114,** No. 1, 1755 (1943); J. Inst. of Met. & Metall. Abs., **13,** 252 (1946) July.

Metallic zinc was attacked by immersing the two ends of a curved strip in oxygen-containing aqueous solutions, which also contained two percent gelatin to increase viscosity, one percent sodium chloride, a trace of acetic acid, and a few drops of phenol red. Of the two alkaline regions which formed around each immersed end at the beginning of the experiment, one grew continuously and the other decreased and finally disappeared. The formation of the asymmetry was promoted by the reduced ion mobility in the viscous solution. The phenomenon is explained by assuming inhomogeneity in the zinc. Iron and aluminum show similar effects.

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## GENERAL CORROSION

**Corrosion Is No Accident.** MAJOR H. E. SMITH, JR. Mech. Eng. **68,** No. 11, 943-948 (1946) Nov.

Causes and prevention of corrosion in aircraft structures are discussed, and studies are described which indicate the importance of frequent inspection and cleanliness in aircraft maintenance. Two types of corrosion in Alclad are defined. The results of a study of eighty C-47 aircraft assigned to the Pacific area are set forth. It is stated that the cause of corrosion was definitely determined to be a lack of proper maintenance and inspection. Various examples of corrosion in aircraft structures are illustrated. Twenty-three illustrations.—AER.

**Fundamental Factors in Corrosion Control.** H. H. UHLIG, Massachusetts Institute of Technology, Chem. Eng. News **24,** No. 23, 3154-3158 (1946).

Several different methods for controlling the corrosion rate of a metal are discussed. The methods are based upon cathodic protection, metallic coatings, inorganic and organic coatings, inhibitors and passivators, alteration of the environment—e.g., oxygen removal, metal purification, and alloying.—AER.

**Modern Metal Protection.** Steel, **119,** pages 108-109 + (1946) Oct. 14.

Basis for comparison of various methods of metal protection is provided by data assembled from the following papers presented before a joint symposium organized by the Cleveland sections of the Electrochemical Society, American Chemical Society, and American Institute of Chemical Engineers: Factors in Corrosion Control, By H. H. Uhlig; Plastic Coatings to Control Metal Corrosion, by S. P. Wilson; Clad Steel Processing Equipment for Chemical and Allied Industries, by E. C. Gosnell; Preparation of Metals for Painting, by R. E. Gwyther; Function of Specification in Electroplating, by C. E. Huessner, Carl O. Durbin, and D. W. Munro; Problems of Automotive Cooling System Corrosion Inhibition, by D. H. Green and R. A. Willihnganz.—BLR.

**Electrochemical Mechanism of Certain Corrosion Processes and Its Practical Implications.** U. R. EVANS, Corr. & Mat. Prot. **3,** 15-18 (1946); Aug.-Sept.

Discusses dry oxidation; electrochemical attack; pitting due to mill-scale; electrochemical mechanism of natural corrosion; soluble inhibitors; inhibitive pigments; metallic coatings; and passivity. Twenty-six references.—BLR.

## INHIBITORS

**Rust-Preventive Compounds.** Aminco Lab. News, **3,** No. 5, 6 (1946) Sept.

Basic inhibitors blended with the proper oil or petrolatum have been reported by the Alox Corp. to be oxygenated hydro-carbons designed in combination with other materials, which protect metals against atmospheric corrosion. They range from the preservative lubricant type to the thin polar film-forming type and are intended primarily to protect surfaces which must later be free of any coating, or on which the coating will be of such a nature as not to interfere with operations if it is

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removed. Although regarded as temporary protection, they will prevent corrosion over a number of years in the case of some products.

## INSPECTION

**Detection of Pores in Protective Coatings.** H. STRZELBA. Paint, Oil & Chem. Rev., **109,** 40 (1946) Oct. 3.

Discusses the various methods used. Some are based on chemical reactions of certain testing fluids with the substrate material, while others rely on the closing of an electrical circuit between the substrate metal and an electrode by means of a suitable electrolyte. Also includes methods used for detached films.—BLR.

**New Tools Used in Corrosion Studies.** Chem. Industries, **59,** No. 3, 483 (1946) Sept.

Three tools used by Westinghouse to probe the atomic nature of the coatings or oxides that form on metal are described—the electron microscope, the electronic diffraction camera, and the vacuum microbalance. Use of each is briefly described and the photomicrograph of the oxide film of aluminum formed at 500° C by oxygen at 0.1 atmospheres in five minutes is shown.

## METAL FAILURE

**Comparative Graphitization of Some Low-Carbon Steels With and Without Molybdenum and Chromium.** G. V. SMITH, S. H. BRAMBIR, and W. G. BENZ. Trans. ASME **68,** 589-595 (1946) Aug.

Study of several experimental heats of steel containing 0.5 percent molybdenum and up to 1.20 percent chromium show that in steels containing 0.5 percent or more chromium, no graphitization occurred in 3000 hours at 1025° F. Finding requires confirmation by study of additional heats. Additional studies relating to the effect of deoxidation practice and of the effect of post-treatment of welds on graphitization are described.—BLR.

**Further Observation of Graphitization in Aluminum-Killed Carbon-Molybdenum-Steel Steam Piping.** R. W. EMERSON and M. MORROW, Pittsburgh Piping & Equipment Co. Paper before ASME, Ann. Mtg., N. Y. C., Nov., 1945, by Jt. ASTM-ASME Res. Comm. on Effect of Temperature on Properties of Metals. Trans. ASME **68,** No. 6, 597-607 (1946) Aug.

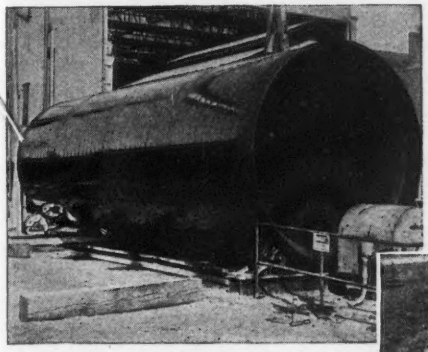
Analysis and cause of "slip-plane" graphitization is studied. This is a condition of graphite segregation along slip planes where local "yielding" or localized plastic deformation had previously occurred. Such graphitization has been found to vary widely from the outside to inside of a pipe and from quadrant to quadrant around the pipe periphery. It has been determined that "nodular" graphite segregation whether of the "isotherm" or slip-plane type is as effective as "chain" graphite in reducing the ductility of low-carbon or low-carbon molybdenum steel. Twenty-two references.

**Cable Sheathing in Aluminum.** Light Metals, **9,** 474-498 (1946) Sept.

Possibility of replacing lead by aluminum is examined critically in the light of economic and technical considerations arising from an exhaustive comparison of these two metals from the standpoints of their

# STOPS CORROSION

## UNDER GROUND, UNDER WATER, OR ABOVE GROUND—Under All Conditions of Soil and Climate



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mechanical and physical properties and amenability to working. Lines of future development in large-scale production are suggested.—BLR.

**Effects of Corrosion on Spot Welded 75ST Alclad Alloy.** MARIO L. OCHIEANO, Prod. Eng. **27,** No. 10, 126-128 (1946) Oct.

Results of tests conducted to determine the weld characteristics, welding technique and corrosion aspects of 75 ST aluminum alloy are reported. It was found that improper material preparation and welding techniques result in erratic bonding in the corona area of the spot welds. This non-uniform bonding is affected by salt spray, resulting in an inconsistent reduction in sheer strengths. Data from tension specimens and data on the preparation and welding of specimens are presented and discussed. Six illustrations.—AER.

**On the Problem of Stress Corrosion.** L. GRAF, Translation of "Zum Problem der Spannungskorrosion," Luftwissen, **7,** No. 5, 1940. National Advisory Committee for Aeronautics, T. M. No. 1090, July, 1946.

Object of the work is, first, to investigate accurately the processes during stress corrosion, in particular for light metal alloys, and, as the first part of the investigation, to determine its laws; and, secondly, to explain its causes for various alloys, and thereby find means for its partial or complete elimination and thus make possible the production of light metal alloys free from stress corrosion. In the present paper, some of the results of the investigation are given and the fundamental problems of stress corrosion are discussed.—AER.

## REFINERY CORROSION

**91-Octane Gasoline Can Be Made By Naphtha Isomerization Process.** Petr. Processing, **1,** No. 2, 140-144 (1946) Oct.

In the isomate process for naphtha isomerization of Standard Oil Co., operating problems caused by the highly corrosive aluminum chloride-hydrocarbon complex catalyst were solved by the use of Lumnite-reinforced lining on nickel-clad walls of reactors, and Hastelloy as material for most valves, fittings and lines. Carbon steel was found satisfactory in some portions of the equipment.

## SURFACE TREATMENT

**Internal Oxidation of Alloys—II. The Effect of Formation of Subscales.** Metal Ind. **69,** 181 (1946) Aug. 30.

Effects of subscales are to act as blocking agents which hinder grain growth when the material is annealed in air; occasionally to produce shallow surface hardening; and to give rise to hydrogen embrittlement when the material is annealed in a reducing atmosphere.—BLR.

**Shot Peening and Its Importance In the Spring Industry.** L. J. WIESCHHAUS, Wire & Wire Prod., **21,** 665-667 (1946) Sept.

Advantages of "shot peening" as compared to "shot blasting," and the methods pursued are described. —BLR.

**Evaluation of Surface-Active Agents. (Continued.)** JAY C. HARRIS, ASTM Bulletin, **1946,** No. 141, 49-53, Aug.

Describes evaluation methods, giving scope, apparatus and procedure

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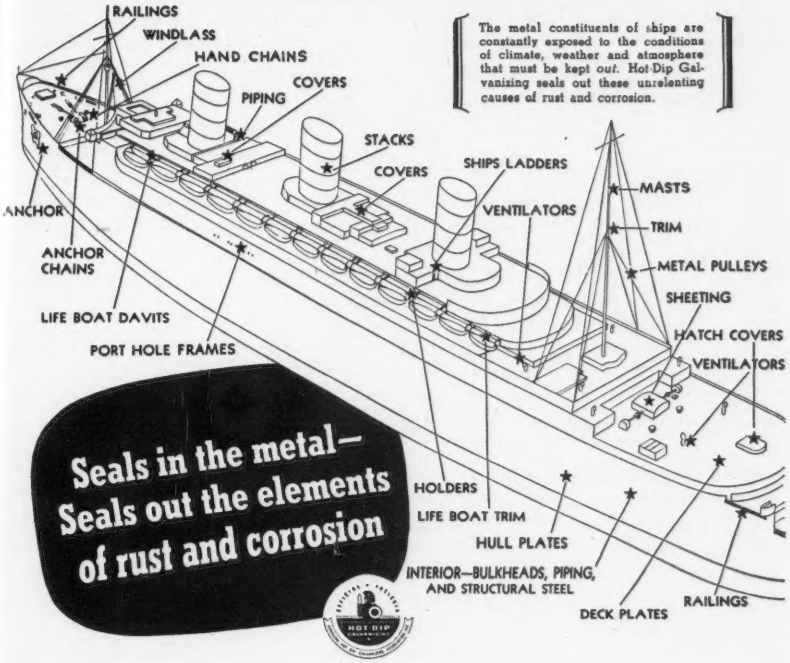


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for acid stability; alkali stability; caustic soda solubility; metallic ion stability; surface and interfacial tension measurements; lime soap dispersion; Draves-Clarkson wetting test; canvas disk wetting test; lather values; organic solvent solubility; and detergent test. Twenty-five references.—BLR.

**Polishing Technique.** L. MABLE, Metal Ind., **69**, 182-184 (1946) Aug. 30.

Deals with choice of personnel, shop layout, polishing materials, polishing bobs, speed of polishing, polishing steel, heat-treated parts, nonferrous metals, and polishing operations.—BLR.

## WATER CORROSION

**Preventing the Fouling of Cooling Waters Reduces Plant's Waste Disposal Costs.** W. B. HART, Petr. Processing, **1**, 102 (1946) Oct.

Article 10 in a series on refinery waste disposal. An early and important step in planning an effective waste disposal program is to adopt means for the prevention, if possible, of the contamination of plant waters. The disposal of uncontaminated wastes is a relatively simple matter. A practical example of such prevention methods is the installation of double discharge lines for water from tubular cooling equipment, so that waste contaminated by leaking oil can be diverted to the line leading to the waste treating plant. Methods are also given for protecting from contamination the waste water from a coil cooler.—GPC.

**Corrosion Damage in Surface Condensers.** F. BORSIG, Maschinenschaden, **20**, 5-16 (1943); Chem. Zentr., **114**, No. 1, 2731 (1943); J. Inst. of Met. & Metall. Abs., **13**, 252 (1946) July.

Types and causes of corrosion are reviewed. Water causes more damage than steam. Brass is very liable to corrode, though the addition of as little as 0.02 percent arsenic protects it.

**The Condensate Pump.** L. J. DAWSON, Ingersoll-Rand Co., Combustion, **18**, No. 3, 28-31 (1946) Sept.

Satisfactory condensate pump design, performance of pump as related to power plant system, materials, vents, etc., are discussed. Use of cast iron casing, bronze impellers and rings, and carbon steel shaft is mentioned. Monel, Ni-Resist, and stainless steel are indicated for heater drain.

**Ground Water Supply and Its Production.** W. M. LEWIS, Layne-New York Co., Inc. Paper before TAPPI, Ann. Mtg., N. Y. C., Feb. 25-8, 1946 Paper Trade J., **123**, No. 11, 117-121 (1946) Sept. 12.

Method of well construction and production operations including recharging are given. Silicon bronze screens are standard in corrosive water, Armco iron screens still being used extensively in noncorrosive waters. Typical deep well pump and well assembly is drawn.

**Corrosion of Plant Equipment By Steam and Water.—I.** R. C. ULMER, Power Plant Eng., **50**, No. 10, 72-75 (1946) Oct.

General theory of corrosion that occurs in power plants, and particularly in boilers; characteristics of

# Where Rustable Conduit Fails in months

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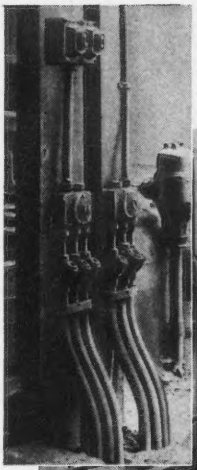
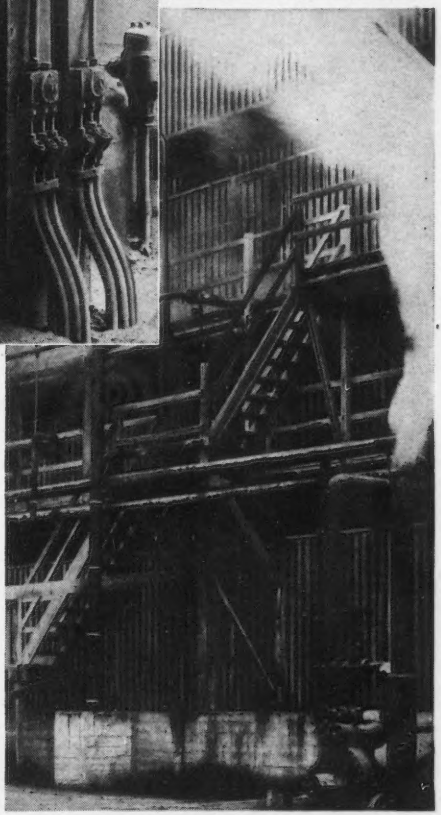


*This concentration of Everdur Electrical Conduit and Everdur fittings at left is located in a moist alcove between cooling towers, yet shows no evidence of corrosive attack.*

*Everdur Electrical Conduit installation at the Torrance Refinery of General Petroleum Corporation after 8 years service in corrosive atmosphere.*



A GOOD EXAMPLE of the ability of Everdur* Copper-Silicon Alloy to withstand severe corrosion is this conduit installation of the Torrance Refinery of General Petroleum Corporation.

Because corrosion-resistant materials were not available, several installations of ordinary conduit were made during the past five years. In the vicinity of the cooling towers, the action of spray from chemically treated water is so severely corrosive that one such installation was replaced twice in two years.

How does Everdur Electrical Conduit stand up under such conditions? This durable material installed eight years ago shows *no effects other than discoloration.* Accordingly, General Petroleum now has definite plans for replacing corroded conduit with Everdur. 46194A

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various types of corrosion; mechanism of corrosion and chemical reactions involved; effects of acid and alkaline solutions; how surface condition modifies corrosive attack; effects of metallic deposit on surface; variation in attack due to temperature changes; causes of embrittlement; methods employed for preventing corrosion and embrittlement in modern steam power plants.—GPC.

**From the Log of Experience.** D. GUTLEBEN, Chem. Eng., **53,** No. 9, 217-218 (1946) Sept.

Corrosion incidents occurring in a sugar plant are briefly described. These include corrosion of steel and cast-iron jet condensers, of a centrifugal basket (which fell apart apparently because of fatigue and dezincification), corrosion and erosion of sugar discharge shafts (eliminated by chromium plating), and painting of sugar-house tanks in the idle season with sugar sirup or lime whitewash.

**Innovations in Gas-Using Appliances in Budapest.** J. BECZKOY, Gas-u. Wasserfach, **86,** 353-357 (1943). J. Inst. of Met. & Metall. Abs., **13,** 276 (1946) July.

Materials recommended for water heaters are: aluminum outer jackets, aluminum alloy threaded parts, rustless steel stripping boxes, aluminum burner, steatite pilot burners, steel water-heater (for continuous service only). Galvanic corrosion is avoided in parts in contact with water by using same material throughout or using coatings.

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